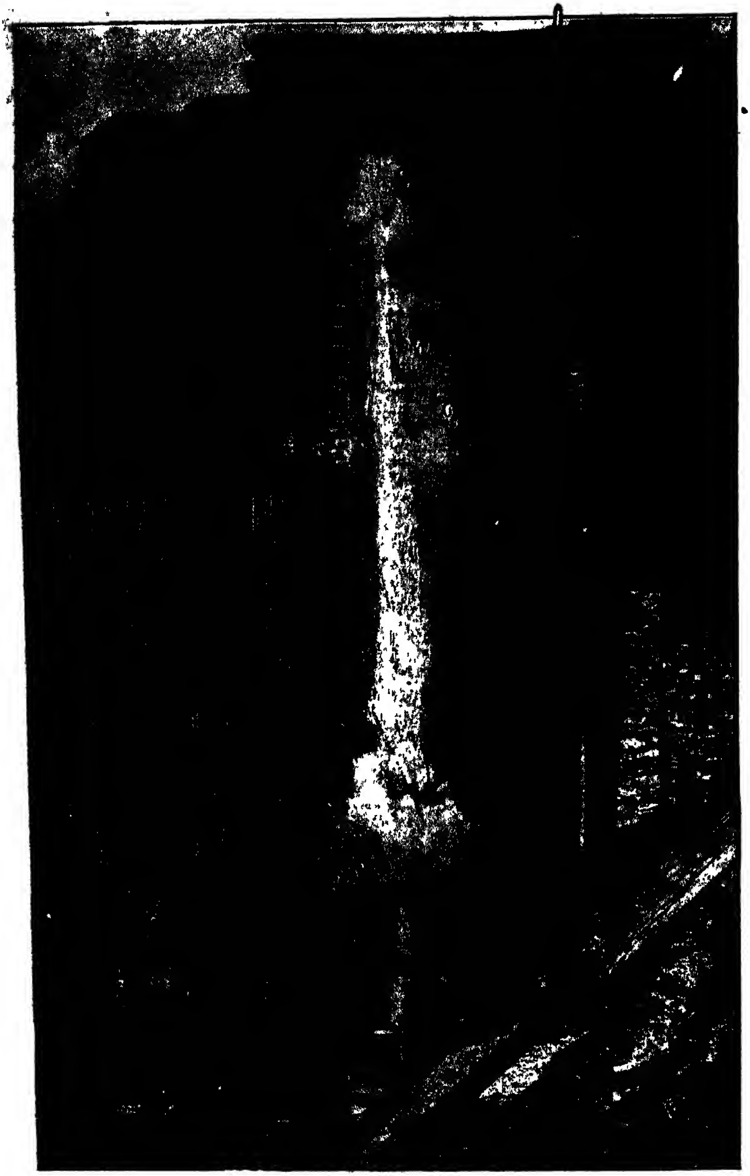
WELL-BORING

FOR WATER, BRINE AND OIL



Effect of a shot fired in hard Rocks at the depth of 863 feet from the surface in a 7½-inch internal diameter Artesian Bored Tube Well, fixed for Messrs ARNOLD, PERRETT & CO The Brewery, Wickwar, Gloucester

WELL-BORING

FOR

WATER, BRINE AND OIL

A MANUAL
OF CURRENT PRACTICE

BY

C. ISLER

HYDRAULIC ENGINEER

SECOND EDITION, REVISED AND ENLARGED

London

E. & F. N. SPON, LTD, 57 HAYMARKET

New York

SPON & CHAMBERLAIN, 123 LIBERTY STREET

1911

PREFACE.

WITH the dissemination of knowledge bearing upon sanitation, and a general recognition of the terrible risks of pollution in wells supplied by surface drainage, it is to be hoped that the days of the shallow dug well are closed for ever.

No price would be too high to pay for absolute security against contamination of the most essential and most largely consumed article of our daily food; and no matter how costly the deep bored well might be in comparison with the shallow dug well, its advantages would outweigh the initial expense.

But to such a high state of efficiency has well-boring now been brought by the most advanced firms who make a speciality of this branch of engineering, that the outlay based on even a five or seven years' supply only is much less in a deep tube well than in a shallow dug well.

Moreover, while the one is *never-failing* both in quantity and in quality, the shortcomings of the other are sure to be emphasised during periods of extreme drought when our needs are most urgent.

In districts where superficial streams are few or entirely wanting, such as in the more tropical portions of our great Australian and South African Colonies, the deep well is absolutely essential to occupation of the land for any

purpose, and the sinking of water bores commands the attention of a Government department. But a vast field yet remains neglected, and there are countless opportunities for private enterprise which would in a few years return immense fortunes. The average annual value of horses, cattle and sheep lost by thirst in the countries named must amount to millions sterling, and a deal of human sickness arises from pollution of air and water by their putrefying carcasses—all which is remediable by deep wells.

Here in England, with generally more than an abundance of surface water, domestic drainage and factory effluents combine to taint all such supplies To the brewer, the mineral-water manufacturer, the dyer, the paper-maker, and in many other industries, a constant and pure water-supply is of the first moment, hence the deep well with its reliable and unsullied flow is fast becoming a recognised indispensable at all factories and works of any pretensions, and many hundreds of such wells, ranging in depth from 150 to 500 feet and in capacity from 2000 to 35,000 gallons per hour, have been bored all over the country in the last few years.

Finally the large domestic consumer has commenced to realise the folly and cost of dependence on the shallow well or the water company, and not only have many country mansions recently been equipped with a deep tube-well and pumping or other water-lifting mechanism, furnishing an abundant supply independent of the weather, and affording increased protection against fire, but the same thing has been done in a great many of the big hotels and other establishments in London and the provinces Besides the inestimable advantages of such an unrestricted regular and

pure supply, the financial gain is not inconsiderable, the cost of pumping being only about $1\frac{1}{2}d.$ per 1000 gallons, and the initial outlay on the boring and equipment being recouped in the first year by the saving on water-rates.

It has been computed by reliable authorities that the water in the chalk strata of the London basin is much more than sufficient to meet all the demands of the same superficial area. Here surely is a "London water scheme," better than any piping from lakes, with its contingent risks of polluted sources, and of a complete famine in case of accident to the conduit.

While water is the fluid most often sought by boring, precisely similar methods are applied to other liquid minerals, such as brine and petroleum, and most of the matter contained in these pages may be regarded as referring indiscriminately to all of them. Chapter VIII. deals more particularly with American oil wells

PREFACE TO THE SECOND EDITION.

THE steady demand for this work necessitates the issue of a second edition New matter has been added to Chapters VIII., IX and X., and, also, an important Table giving particulars of many wells sunk in this country.

C. ISLER.

ARTESIAN WORKS, BEAR LANE,
SOUTHWARK, LONDON, S E

CONTENTS.

WELL-BORING

CHAPTER I.

GEOLOGICAL CONSIDERATIONS.

Soakage.—Porous soils, such as sand and gravel, absorb water with rapidity, and consequently their surface soon dries up after showers. A well sunk in these soils may penetrate to considerable depths before meeting with water; but water, nevertheless, is usually found on approaching some lower part of the porous formation where it rests on an impervious bed, for here the water, unable to make its way downwards in a direct line, accumulates as in a reservoir, and is ready to ooze out into any opening which may be made, in the same manner as sea-water will filter into and fill any hollow dug in the sands of the shore at low tide. A spring, then, is the lowest overflow-point or lip of an underground reservoir of water in the stratification. A well sunk in such strata will most probably furnish, besides the volume flowing from the spring, an additional supply of water, inasmuch as it may give access to the main contents of the reservoir.

Transmission of water through a porous medium being so rapid, it may easily be understood why springs are thrown out on the side of a hill, where the upper set of

strata consist of chalk, sand and other absorptive substances, whilst those lying beneath are composed of clay or other non-absorptive soils. The principal reasons why the water does not ooze out everywhere along the line of junction of the two formations, so as to form one continuous land-soak instead of creating a few springs only, and these oftentimes far distant from each other, are, firstly, the concentration of the water at a few points due to existence of inequalities in the upper surface of the impermeable stratum, which lead the water, as valleys do on the external surface, into certain low levels and channels, and secondly, the frequency of rents and fissures acting as natural drains.

That the generality of springs owe their supply to atmospheric sources is evident from this, that they vary in the different seasons of the year, becoming languid or entirely ceasing to flow after long droughts, and being again replenished after a continuance of rain. Many of them are probably indebted for the constancy and uniformity of their volume to the great extent of subterranean reservoirs with which they communicate, and the time required for these to empty themselves by percolation. Such a gradual and regulated discharge is exhibited, though in a less perfect degree, in all great lakes, for these are not sensibly affected in their levels by a sudden shower, but are only slightly raised, and their channels of efflux, instead of being swollen suddenly like the bed of a torrent, carry off the surplus water gradually

An "artesian" well—so called from the province of Artois, in France—is a shaft sunk or bored through non-absorptive strata, until a water-bearing stratum is tapped, when the water is forced upwards by the hydrostatic pressure due to the superior level at which the rain-water was received The term artesian was originally only

applied to wells which overflowed, but nearly all deep wells are so called, without reference to their water-level, if they have bore-holes.

Among the causes of failure of artesian wells, may be mentioned the numerous rents and faults which occur in some rocks, and the deep ravines and valleys by which many countries are traversed, for when these natural lines of drainage exist, there remains only a small quantity of water to escape by artificial issues. The well-borer is also liable to be baffled by the great thickness either of absorp-

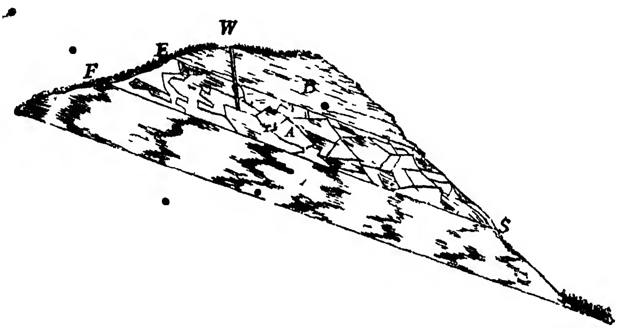


FIG. 1 —LIMITED OUTCROP OF ABSORPTIVE STRATUM.

tive or non-absorptive strata; or by the dip of the beds, which may carry off the waters from adjoining high lands to some trough in an opposite direction—as when the borings are made at the foot of an escarpment where the strata incline inwards, i.e. in a direction opposite to the face of the cliffs.

As instances of the way in which the character of the strata may influence the water-bearing capacity of any given locality, the following examples are cited from Latham.

Fig. 1 illustrates the causes which sometimes conduce to

a limited supply of water in artesian wells. Rain descending on the outcrop E F of the absorptive stratum A, which lies between the non-absorptive strata B B, will make its appearance in the form of a spring at S; but such spring will not yield any great quantity of water, as the area E F, which receives the rainfall, is limited in its extent, and the well bored at W into the absorptive stratum A would not be likely to furnish a large supply of water—if, indeed, it afforded any.

The effect of a fault is shown in Fig 2. A spring will in all probability make its appearance at the point S, and

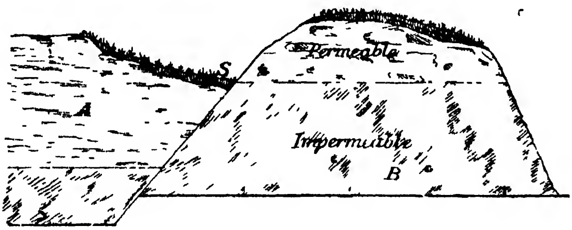


FIG 2—EFFECT OF FAULTING.

will give large quantities of water, the whole body of water flowing through the absorptive stratum A being intercepted by being thrown against the non-absorptive stratum B.

Absorptive rock intersected by a dyke, and overlying a non-absorptive stratum, is seen in Fig 3 The water flowing through A, if interrupted by a dyke D, will appear at S in the form of a spring; and if the area of A is very great, then the spring S will be very copious.

As to the depth necessary to bore certain wells in cases similar to that shown in Fig. 4. Owing to the fault, a well at A would require to be bored deeper than the well B, although both wells derive their supply from the same

description of strata. If there were any inclination in the water-bearing strata, or if there were a current of water

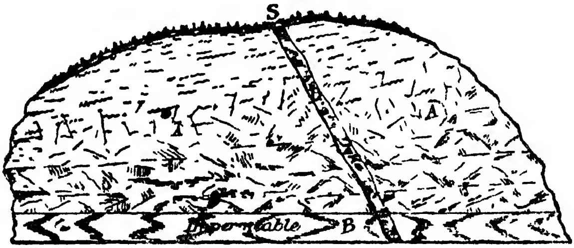


FIG. 3.—EFFECT OF DYKE

only in one direction then one of the wells would prove a failure, owing to the proximity of the fault, while the other would furnish an abundant supply of water.

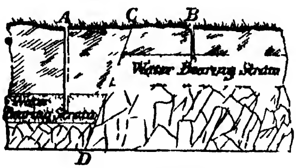


FIG 4.—DEPTHS

Volume—It should be borne in mind that there are two primary geological conditions upon which the quantity of water that may be supplied to the water-bearing strata depends these are—the extent of superficial area presented, by which the quantity of rain-water received on their surface in any given time is determined, and the character and thickness of the strata, as by this the proportion of water that can be absorbed, and the volume which the whole mass of the absorptive strata can transmit, are regulated The operation of these general principles will constantly vary in accordance with local phenomena,

all of which must, in each separate case, be taken into consideration.

Mere remoteness from hills or mountains need not discourage the making of trials, for the waters which fall on these higher lands readily penetrate to great depths through highly-inclined and vertical strata, or through the fissures of shattered rocks; and, after flowing for a great distance, they often reascend by way of other fissures, so as to approach the surface in the lower country. Here they may be concealed beneath a covering of undisturbed horizontal beds, which it may be necessary to pierce in order to reach them. The course of water flowing underground is not strictly analogous to that of rivers on the surface; there being, in the one case, a constant descent from a higher to a lower level, from the source of the stream to the sea; whereas, in the other, the water may at one time sink far below the level of the ocean, and afterwards rise again high above it

It is evident that a series of permeable strata, encased between two impermeable formations, can receive a supply of water at those points only where they crop out and are exposed on the surface of the land The primary condition affecting their usefulness depends upon the fall of rain in the district where the outcrop takes place, the quantity of rain-water which any absorptive strata can gather being in the same ratio as their respective areas Each inch of mean annual fall in any district represents a daily average of practically 40,000 gallons of rain-water per square mile. It is therefore a matter of essential importance to ascertain, with as much accuracy as possible, the area of exposed surface of any water-bearing deposit, so as to determine the maximum quantity of rain-water it is capable of receiving.

Whatever may be the absorbent power of the strata, the

yield of water will be more or less diminished whenever the channels of communication have suffered break or fracture. If the strata remained continuous and unbroken, it would only be necessary to ascertain their dimensions and lithological character in order to determine their actual water value. But where the strata are broken, the interference with subterranean transmission of water will be proportionate to the extent of the disturbance

Every permeable stratum may afford water, and its ability to do this and the quantity it can yield depend upon its position and extent. When underlaid by an impervious stratum, it constitutes a reservoir of water from which a supply may be drawn by means of a sinking or a bore-hole. If the permeable stratum be also overlaid by an impervious stratum, the water will be under pressure, and will ascend in the bore-hole to a height depending on the height of the points of infiltration above the bottom of the bore-hole The quantity to be obtained in such a case, as already pointed out, will depend upon the extent of surface possessed by the outcrop of the permeable stratum

In searching for water under such conditions, a careful examination of the geological features of the district must be made Frequently an extended view of the surface of the district, such as may be obtained from an eminence, and a consideration of the particular configuration of that surface, will be sufficient to enable the practical eye to discover the various routes which are followed by the subterranean water, and to predicate with some degree of certainty that at a given point water will be found in abundance, or that no water at all exists at that point To do this, it is sufficient to note the dip and the surfaces of the strata which are exposed to the rains. When these strata are nearly horizontal, water can penetrate them only

through their fissures or pores; when, on the contrary, they lie at right angles, they absorb the larger portion of the water that falls upon their outcrop. When such strata are intercepted by valleys, numerous springs will exist. But if, instead of being intercepted, the strata rise around a common point, they form a kind of irregular basin, in the centre of which the water will accumulate In this case the surface springs will be less numerous than when the strata are broken. But it is possible to obtain water under pressure in the lower portions of the basin, if the point at which the trial is made is situate below the outcrop.

If the strata consist of sand, water will pass through them with facility, and they will also hold a considerable quantity in the interstices between their component grains; whereas a bed of pure clay will not allow of the passage of water. These are the two extremes of the case. The intermixture of these materials in the same bed will, of course, modify the transmission of water according to the relative proportions. Sand of ordinary character will hold on an average rather more than one-third of its bulk of water, or 2 to 2½ gallons per cubic foot. In strata so composed the water may be termed free, as it passes easily in all directions, and under the pressure of a column of water, it is comparatively but little impeded by capillary attraction. These are the conditions of a true permeable stratum Where the strata are more compact and solid, as in sandstone, limestone and oolite, although all such rocks imbibe more or less water, yet the water so absorbed does not pass freely through the mass, but is held in the pores of the rock by capillary attraction, and parted with very slowly, so that in such deposits water can be freely transmitted only in the planes of bedding and in fissures.

If the water-bearing deposit is of uniform lithological character over a large area, then the proposition is reduced to its simplest form, but when the strata consist of variable mineral ingredients, it becomes essential to estimate the extent of these variations

Rainfall.—Rain is most capricious, both as regards its frequency and the amount which falls in a given time. In some places it rarely or never falls, whilst in others it rains almost every day, and there does not yet exist any theory from which a probable estimate of the rainfall in a given district can be deduced, independently of direct observation. But a workable average of the quantity of rain to be expected in any particular place, may be judged from careful and continued observations with a rain-gauge The mouth of the gauge must be set quite level, and so fixed that it will remain so; it should never be less than 6 inches nor more than 12 inches above the ground, except when a greater elevation is absolutely necessary to obtain a proper exposure. It must be placed on level ground, unshaded and unsheltered, and away from all structures and growths of every kind, at least as many feet from their base as they are in height.

For snow, three methods may be adopted (*a*) melt what is caught in the funnel, and measure that as rain; (*b*) select a place where the snow has not drifted, invert the funnel, and, turning it round, lift and melt what is enclosed, (*c*) measure with a rule the average depth of snow, and take one-twelfth as the equivalent of water Some observers use a cylinder of the same diameter as the rain-gauge, and of considerable depth, if the wind is at all rough, all the snow is blown out of a flat-funnelled rain-gauge.

A "drainage area" is almost always a district of country

enclosed by a ridge or watershed line, continuous except at the place where the waters of the basin find an outlet. It may be, and generally is, divided by branch ridge-lines into a number of lesser basins, each drained by its own stream into the main one.

When a catchment basin is very extensive, it is advisable to measure the smaller basins of which it consists, as the depths of rainfall in them may be different; sometimes, also, for the same reason, those basins may be divided into portions at different distances from the mountain chains, where rain-clouds are chiefly formed.

The exceptional cases, in which the boundary of a drainage area is not a ridge-line on the surface of the country, are those in which the rain-water sinks into a porous stratum until its descent is stopped by an impervious stratum, and in which, consequently, one boundary at least of the drainage area depends on the figure of the impervious stratum, being, in fact, a ridge-line on the upper surface of that stratum, instead of on the ground, and very often marking the upper edge of the outcrop of that stratum. If the porous stratum is partly covered by a second impervious stratum, the nearest ridge-line on the latter stratum to the point where the porous stratum crops out will be another boundary of the drainage area. In order to determine a drainage area under these circumstances, it is necessary to have a geological map and sections of the district.

The most important data respecting depth of rainfall, for practical purposes, are: least annual rainfall; mean annual rainfall; greatest annual rainfall; distribution of rainfall at different seasons, especially the longest continuous drought; and greatest flood rainfall, or continuous fall of rain in a short period.

The available rainfall is that part of the total which remains to be stored in reservoirs, or carried away by streams, after deducting loss through evaporation, through permanent absorption by plants and by the ground, and other causes.

The proportion borne by available to total rainfall varies very much: it is affected by the rapidity of the rainfall, the compactness or porosity of the soil the steepness or flatness of the ground, the nature and quality of the vegetation upon it, the temperature and moisture of the air (regulating the rate of evaporation), the existence of artificial drains, and other circumstances. The following are examples:—

Ground	Available Rainfall ÷ Total Rainfall
Steep surfaces of granite, gneiss, and slate	nearly 1
Moorland and hilly pasture	·8 to ·6
Flat cultivated country	·5 to ·6
Chalk	0

Deep-seated springs and wells give ·3 to ·4 of the total rainfall. In chalk districts it has been found that evaporation is about 34 per cent., and the quantity carried off by streams, 23 per cent , leaving 43 per cent., which sinks below the surface to form springs

In formations less absorbent than the chalk, it is calculated by some authorities that streams carry off one-third, that another third evaporates, and that the remaining third of the total rainfall sinks into the earth But if they are correct in allowing one-third for evaporation in the cool and humid climate of England, 100 per cent would not be too much in such arid districts as the interiors of Australia and Africa.

The following table gives the mean annual rainfall in various parts of the world —

TABLE OF RAINFALL. Collected by G. J. Symons.

Country and Station	Period of Observations	Latitude	Mean Annual Fall
EUROPE.	years	° ′	in
AUSTRIA—Cracow	5	50 4 N	33·1
Prague	47	50 5	15·1
Vienna	10	48 12	19·6
BELGIUM—Brussels	20	50 51	28 6
Ghent	13	51 4	30·6
Louvain	12	50 33	28 6
DENMARK—Copenhagen	12	55 41	22 3
FRANCE—Bayonne	10	43 29	56 2
Bordeaux	32	44 50	32 4
Brest	30	48 23	38 8
Dijon	20	47 14	31·1
Lyons		45 46	37·0
Marseilles	60	43 17	19·0
Montpelier	51	43 36	30 3
Nice	20	43 43	55·2
Paris	44	48 50	22·9
Pau	12	43 19	37·1
Rouen	10	49 27	33 7
Toulon		43 4	19·7
Toulouse	52	43 36	24 9
GREAT BRITAIN—			
England, Exeter	40	50 44	33 0
„ Lincoln	40	53 15	20 0
„ London	40	51 31	24·0
„ Manchester	40	53 29	36·0
Wales, Cardiff	40	51 28	43 0
„ Llandudno	40	53 19	30·0
Scotland, Aberdeen	40	57 8	31 0
„ Edinburgh	40	55 57	24 0
„ Glasgow	40	55 52	39·0

TABLE OF RAINFALL—*continued.*

Country and Station.	Period of Observations	Latitude	Mean Annual Fall
GREAT BRITAIN—*continued*	years	° ′	in
Ireland, Cork	40	51 54 N	40 0
,, Dublin	40	53 23	30 0
,, Galway	40	53 15	50 0
HOLLAND—Rotterdam	.	51 55	22 0
ICELAND—Reykjavik	5	64 8	28 0
IONIAN ISLES—Corfu	22	39 37	42 4
ITALY—Florence	8	43 46	35 9
Milan	68	45 29	38 0
Naples	8	40 52	39·3
Rome	40	41 53	30 9
Turin	4	45 5	38 6
Venice	19	45 25	34 1
MALTA		35 54	15 0
NORWAY—Bergen	10	60 24	84 8
Christiania		59 54	26 7
PORTUGAL—Coimbra (in Vale of Mondego)	2	40 13	224 0?
Lisbon	20	38 42	23 0
PRUSSIA—Berlin	6	52 30	23 6
Cologne	10	50 55	24 0
Hanover	3	52 24	22 4
Potsdam	10	52 24	20 3
RUSSIA—Archangel	14	64 32	14 5
Astrakan	1	46 24	6 1
Finland, Uleaborg	4	65 0	13 5
St Petersburg		59 56	16·2
SICILY—Palermo	24	38 8	22 8
SPAIN—Madrid		40 24	9 0
Oviedo	1	43 22	111·1
SWEDEN—Stockholm	8	59 20	19 7
SWITZERLAND—Geneva	72	46 12	31 8
Great St. Bernard	43	45 50	58 5
Lausanne	8	46 30	38 5

TABLE OF RAINFALL—*continued.*

Country and Station	Period of Observations	Latitude	Mean Annual Fall
ASIA.	years	° ′	in
CEYLON—Adam's Peak .		6 50 N	100 0
Colombo .	.	6 56	91·7
Kandy . . .	..	7 18	84·0
CHINA—Canton . .	14	23 6	69 3
Macao .		22 24	68 3
Pekin . .	7	39 54	26·9
INDIA—Bombay .	33	18 56	84·7
Calcutta	20	22 35	66·9
Cherrapongee	.	25 16	610·3?
Darjeeling		27 3	127·3
Madras .	22	13 4	44·6
Mahabuleshwur	15	17 56	254·0
Malabar, Tellicherry	..	11 44	116·0
Palamcotta	5	8 30	21·1
Patna		25 40	36·7
Poonah	4	18 30	23·4
MALAYSIA—Pulo Penang	.	5 25	100·5
Singapore .	.	1 17	190·0
PERSIA—Lencoran . .	3	38 44	42 8
Ooroomiah	1	37 28	21·5
RUSSIA—Barnaoul . . .	15	53 20	11·8
Nertchinsk	12	51 18	17·5
Okhotsk . .	2	59 13	35·2
Tiflis . .	6	41 42	19·3
Tobolsk . .	2	58 12	23·0
TURKEY—Palestine, Jerusalem .	{ 14	31 47	65 0?
	3	31 47	16·3
Smyrna	..	38 26	27·6

TABLE OF RAINFALL—*continued*.

Country and Station	Period of Observations	Latitude	Mean Annual Fall
AFRICA.			
	years	° ′	in
ABYSSINIA—Gondar		12 36 N.	37 3
ALGERIA—Algiers	10	36 47	37 0
Constantina	.	36 24	30·8
Mostaganem	1	35 50	22 0
Oran	2	35 50	22 1
ASCENSION .	2	8 8 S.	11 5
CAPE COLONY—Cape Town	20	33 52	24·3
GUINEA—Christiansborg	.	5 30 N	19 2
MADEIRA .	4	33 30	30·9
MAURITIUS—Port Louis		20 3 S	35·2
NATAL—Maritzburg		29 36	27·6
ST HELENA .	3	15 55	18 8
SIERRA LEONE .		8 30 N.	86·0
TENERIFFE .	2	28 28	22·3
NORTH AMERICA			
BRITISH COLUMBIA—New Westminster	3	49 12 N	54 1
CANADA—Montreal, St Martin's	2	45 31	47 3
Toronto .	16	43 39	31 4
HONDURAS—Belize	1	17 29	153·0
MEXICO—Vera Cruz	.	19 12	66 1
RUSSIAN AMERICA—Sitka	7	57 3	89·9
UNITED STATES—Arkansas, Fort Smith .	15	35 23	42 1
California, San Francisco	9	37 48	23·4
Nebraska, Fort Kearney	6	40 38	28·8
New Mexico, Socorro	2	34 10	7·9
New York, West Point	12	41 23	46 5
Ohio, Cincinnati	20	39 6	46 9
Pennsylvania, Philadelphia	19	39 57	43·6
South Carolina, Charlestown .	15	32 46	48·3
Texas, Matamoras .	6	25 54	35·2

TABLE OF RAINFALL—*continued.*

Country and Station	Period of Observations	Latitude.	Mean Annual Fall
NORTH AMERICA—*continued.*	years	° ′	in
WEST INDIES—Antigua		17 3 N	39·5
Barbadoes	10	13 12	75·0
,, St Philip	20	13 13	56·1
Cuba, Havana	2	23 9	50·2
,, Matanzas	1	23 2	55·3
Grenada		12 8	126·0
Guadeloupe, Basseterre		16 5	126·9
,, Matonba		16 5	285·8
Jamaica, Caraib		18 3	97·0
,, Kingstown		17 58	83·0
St. Domingo, Cape Haitien		19 43	127·9
,, Tivoli		19 0	106·7
Trinidad		10 40	62·9
Virgin Isles, St Thomas		18 17	60·6
,, Tortola		18 27	65·1
SOUTH AMERICA			
BRAZIL—Rio Janeiro		22 54 S	58·7
S. Luis de Maranhao		3 0	276·0
COLOMBIA—La Baja	6	7 22 N	54·1
Marmato	15	5 29	90·0
Santa Fé de Bogota	6	4 36	43·8
GUIANA—Cayenne	6	4 56	138·3
Demerara, George Town	5	6 50	87·9
Paramaribo		6 0	229·2
VENEZUELA—Cumana		10 27	7·5
Curaçao		12 15	26·6

TABLE OF RAINFALL—*continued.*

Country and Station	Period of Observations.	Latitude.	Mean Annual Value.
AUSTRALASIA.			
	years	° ′	in
NEW SOUTH WALES—Bathurst	3	33 24 S.	22·7
Deniliquin	2	35 32	13 8
Newcastle	3	32 57	55·3
Port Macquarie	12	31 29	70·8
Sydney	6	33 52	46·2
NEW ZEALAND—Auckland	2	36 50	31·2
Christchurch	3	43 45	31·7
Nelson	2	41 18	38·4
Taranaki	2	39 3	52·7
Wellington	2	41 17	37·8
SOUTH AUSTRALIA—Adelaide	6	34 55	19·2
TASMANIA—Hobart	12	42 54	20 3
VICTORIA—Melbourne	6	37 49	30·9
Port Philip	11	38 30	29 2
WEST AUSTRALIA—Albany	.	35 0	32·1
York	1	31 55	25·4
POLYNESIA.			
SOCIETY ISLANDS—Tahiti Papiete	5	17 32 S	45·7

Water-bearing Strata.—Among absorptive beds, mention may first be made of the "Drift." This superficial formation consists mainly of beds of sand and gravel. Having been formed by the action of flowing water, it is very irregular in thickness, and exists frequently in detached masses; this irregularity is due to inequalities of the surface at the period when the drift was brought down.

Hollows then existing would be filled up, while on level surfaces no detritus would be deposited, or, if deposited, would be subsequently removed by denudation. Hence it is not safe to infer, when boring through deposits of this character, that the same, or nearly the same, thickness will be found at even a few yards' distance. In basins and in broad valleys, this deposit may exist to great depth. The absorptiveness of the beds will depend, of course, wholly upon the nature of the deposit Some rocks produce deposits through the whole of which water percolates readily, while others allow a passage only through such fissures as may exist Sand and gravel constitute an extremely absorbent medium, while an argillaceous (clay) bed may be wholly impervious In mountainous districts, springs may often be found in the drift, but their existence will then depend upon the position and character of the rock strata. Thus, if the drift cover an elevated and extensive slope of a nature similar to that of the rocks by which it is formed, springs due to infiltration through this covering will certainly exist near the foot of the slope Upon the opposite slope, the small spaces existing between the different beds of rock receive these infiltrations directly, and serve to completely drain the deposit. If, however, the foliations or the joints of the rocks afford no issue to the water, whether such circumstance be due to the character of their formation, or to the stopping up of the issues by the drift itself, these results will not be produced.

Another superficial formation, termed "Alluvium" or "alluvion," and often (ungrammatically) "alluvial," is similarly composed of fragments of various strata carried away and re-deposited by flowing water; it differs, in fact, from drift only in being more extensive and regular, and, generally, in being composed of elements brought from a greater

distance and having no analogy to the strata with which it is now found in contact. It embraces sand, gravel, rolled pebbles, marls and clays The older deposits often occupy very elevated districts, which they overlie throughout a large extent of surface. The permeability of alluvial beds allows the water to flow away subterraneously to great distances from the points at which it enters. Springs are common. As the surface covered by the deposit is extensive, the water circulates from a distance through permeable strata often overlaid by others that are non-absorptive If at a considerable distance from the points of infiltration, and a lower level, a boring be put down, the water will ascend in the bore-hole in virtue of its tendency to place itself in equilibrium

The sedimentary beds of Secondary and Tertiary geological ages, lying beneath the more recent formations just described, are far more extensive and yield much larger quantities of water

The Chalk is the great water-bearing stratum for the larger portion of the South of England, and here water circulates through fissures A rule sometimes given for the level at which water may be found in this stratum is, "Take the level of the highest source of supply, and that of the lowest to be found The mean level will be the depth at which water will be found at any intermediate point, after allowing an inclination of at least 10 feet per mile" This rule will also apply to the Greensand formation, which contains large quantities of water, and more evenly distributed than in the Chalk. The Gault Clay is interposed between the Upper and the Lower Greensand, the latter of which also furnishes good supplies. In boring into the Upper Greensand, caution should be observed so as not to pierce the Gault Clay, because water which permeates

through that layer becomes contaminated with various saline, ferruginous and other impurities.

Water is found in the Upper and Lower Oolites, between which are certain clays, separated by the "coral rag." Instances occur in England where the so-called Oxford Clay is met with immediately below another bed named the Kimmeridge, rendering useless any attempt at boring, because the water in the Oxford Clay is generally so impure as to be unfit for use. With regard to finding water in the Oolitic Limestone, it is impossible to determine with any amount of precision the depth at which it may be reached, owing to the numerous faults which occur in the formation. The Oolitic rocks are very porous, absorbing and holding enormous volumes of water. In this respect they are equal if not superior to the Chalk itself, and selected analyses indicate that they are not inferior to the New Red Sandstone in the energy with which they oxidise and destroy organic matter present in waters percolating through them. Though their waters are generally hard, the hardness is chiefly of a temporary character, capable of being softened by Clark's process, so as to average 6°·8 instead of 20°·6, the supply is bright, sparkling, and palatable, excellent for drinking and all domestic purposes except washing, for which the addition of lime renders it fit.

Lower in the sequence of formations are the Lias beds (Upper Lias, Marlstone, and Lower Lias). In the Marlstone, between the upper and lower beds of the Lias, may be found a large supply of water; but the level of this is as a rule so low that it will not rise to the surface through a boring.

In the New Red Sandstone, also, to find water, borings must be made to considerable depth; but where this formation exists, a copious supply can be confidently anticipated. It may be looked upon as almost equally permeable

in all directions, and the whole mass be regarded as a reservoir up to a certain level. Its water is clear, wholesome, and pleasant to drink, also well adapted for the purposes of bleaching, dyeing, and brewing; at the same time it must be admitted that its hardness, in other words the proportions of carbonates of lime and magnesia it contains, is subject to considerable variation. As a general rule, it may be considered as occupying a position intermediate between the hard water of the Chalk and the soft water derived from superficial sources Having but a small proportion of saline ingredients, and being absolutely free from artificial contaminations (such as sewage and manufacturing effluents), it possesses incalculable advantages over water from rivers and surface drainage. Many large towns are now partially or entirely supplied with water pumped from deep bores in this Sandstone, and many millions of acres in central Australia have only ceased to be waterless since numbers of bores have been sunk to reach similar beds.

The primary rocks afford but little water. Having been subjected to violent convulsions, they are thrown into every possible position, and broken by numerous fissures, and no permeable stratum being interposed, as in the more recent formations, no reservoir of water exists. In the unstratified rocks, the water circulates in all directions through the fissures that traverse them, and thus occupies no fixed level It is also impossible to discover by surface examination where the fissures may be struck by boring. For purposes of water supply, therefore, these rocks are of little importance It must be remarked here, however, that large quantities of water are frequently met with in the Magnesian Limestone and the Lower Red Sandstone, which form the upper portion of the primary series.

It is hardly necessary to say that rocks of igneous origin are devoid of water-bearing strata, and though the extraordinary anomaly may be seen in Australia of borings for water put down in solid granite, this is due to pernicious political influences and in spite of the protests of professional advisers.

CHAPTER II.

DUG WELLS

SLOWLY but surely the "sunk" well, with its huge excavation and brick curbing, is going out of existence, and no regret need follow it From its very nature, it is absurdly expensive and adapted only to shallow sinking, but much worse than this is the fact that its sources of water supply are almost invariably tainted. Very few pages will suffice for this chapter

Marking-off.—Sinking is commenced by marking off upon the ground a circle 12 or 18 in. greater than the intended internal diameter of the well. Its centre must be carefully preserved, and everything must be true to it, the plumb-line being frequently used to test the vertical position of the sides.

Under-pinning.—To sink by under-pinning, an excavation is first made to such depth as the strata will allow without falling in At the bottom is laid a "curb" or flat ring, its internal diameter equals the intended clear diameter of the well, and its breadth the thickness of the brickwork. It is made of oak or elm planks 3 to 4 in. thick, either in one layer fished at the joints with iron, or in two layers breaking joint, and spiked or screwed together. On this, to line the first division of the well, a cylinder of brickwork, technically called "steining," is built in mortar or cement In the centre of the floor is dug a pit, at the bottom of which is laid a small platform of boards, then

by cutting notches in the side of the pit, several raking props are inserted, their lower ends abutting against a foot-block, and their upper ends against the lowest setting, so as to give temporary support to the curb with its load of brickwork The pit is enlarged to the diameter of the well , on the bottom of the excavation is laid a new curb. on which is built a new division of brickwork, giving permanent support to the upper curb ; the raking props and their foot-blocks are removed , a new pit is dug ; and so on as before The earth must be firmly packed behind the steining.

In a common modification of this method, a wooden curb is laid at the bottom of the excavation , the brick steining is built upon it and carried to the surface , the earth is excavated flush with the interior sides of the well, so that the earth beneath the curb supports the brickwork above ; when the excavation has been carried as far as convenient, recesses are made in the earth under the previous steining, and in these recesses the steining is carried up to the previous work ; when thus supported, the intermediate portions of earth between the sections of brickwork carried up are cut away, and the steining is completed.

Drum-curbing.—A "drum-curb," which may be either of wood or iron, consists of a flat ring for supporting the steining, and of a vertical hollow cylinder or drum of the same outside diameter as the steining, supporting the ring within it and bevelled to a sharp edge below. The rings or ribs of a wooden curb are formed of two thicknesses of elm plank 9 by 1½ in , giving a total thickness of 3 in. The outside cylinder or lagging is made from 1½-in. yellow pine planks. It may be strengthened by additional rings and by brackets. In large curbs, the rings are placed about 3 ft. 6 in. apart. When the well has been sunk as far as the

earth will stand vertical, the drum curb is lowered into it, and the building of the brick cylinder is commenced, each course of bricks being completed before laying another, in order that the curb may be loaded equally all round. The earth is dug away from the interior of the drum, and this, together with the gradually increasing load, causes the sharp lower edge of the drum to sink into the earth · thus the digging of the well bottom, the sinking of the drum-curb and its brick lining, and the building of the steining at the top, go on together. Care must be taken to so regulate the digging that the well shall sink vertically Should the friction of the earth against the outside of the drum become so great as to stop its descent before the requisite depth is attained, a smaller well may be sunk in the interior of the first a well so stopped is said to be "earth-fast" This plan is successful only in sandy soils and to moderate depths.

The curbs are often supported by iron rods (with screws and nuts) from cross-timbers over the mouth of the well, as the excavation proceeds, brickwork is piled on above, and the weight of the steining carries down the curb until it becomes earth-bound

Materials for Steining.—The materials that have been successfully used in lining or steining are brick, stone, timber, and iron.

Brickwork is universally used in England, but not unfrequently it fails, through admitting impure water (when under great pressure), or through becoming disjointed (from settlement due to draining a running sand-bed), or the collapse of the well.

Brick steining is either laid dry or in cement, 9-in. work being used for large wells and 4½-in. for small wells. Figs. 5 and 6 show the method of laying for 9-in work, and Fig. 7

for 4½-in. The bricks are laid flat, breaking joint. To keep out moderate land-springs, clay-puddle or concrete is introduced at the back of the steining; for most purposes,

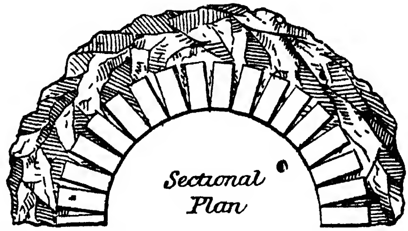


FIG. 5.—BRICK STEINING

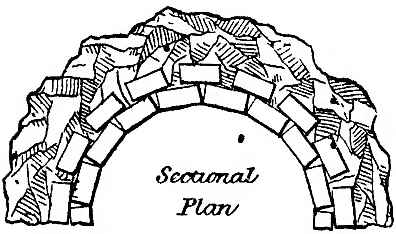


FIG. 6.—BRICK STEINING

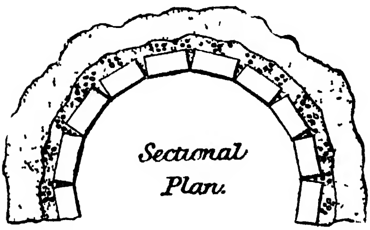


FIG. 7.—BRICK STEINING

concrete is the better, as, in addition to its impervious character, it adds greatly to the strength of the steining. A ring or two of brickwork in cement is often introduced

at intervals varying from 5 to 12 ft., to strengthen the shaft and facilitate construction.

Stone of fair quality, capable of withstanding compressive strains, is good in its way, but inasmuch as it requires a great deal of labour to fit it for its place, it cannot often successfully compete with brickwork. In selecting a stone, attention must be paid not only to its durability but also to freedom from soluble ingredients which might impair the purity of the water.

Timber is objectionable on account of its liability to decay, when it not only endangers the structure, but also to some extent fouls the water. It is very largely used in the preliminary operations of sinking most wells, and in lining the shafts of the salt wells of Cheshire it endures for a great number of years, the brine acting as a preservative

Iron is of modern application, and is extensively employed, it being capable of bearing great compressive strains and of effectually excluding the influx of such waters as it may be desirable to keep out, and not liable to decay under ordinary circumstances. Baldwin Latham mentions instances in his practice of successful recourse to iron cylinders, where 4 or 5 rings of brickwork set in the best cement failed to keep out brackish waters

CHAPTER III

DRIVEN TUBE WELLS

Scope.— For limited depths and supplies, and in strata which, though, perhaps, hard and compact, are not composed of actual rock, the driven tube forms a most useful well, capable of being sunk at great speed, and drawing its water from a horizon below most risks of contamination by surface drainage Since the driven tube well has been in use the Author has introduced many improvements.

Before locating one of these wells, it is advisable to ascertain the depth at which water is found in the district, when possible, either by reference to a geological map or by sounding existing dug wells Thus may be gained an approximate idea of the depth to which the tube well must be driven; but variations of the strata occur in very short distances, and no guide is infallible.

If beds of stiff clay or true rock are encountered, it is best to abandon the spot and try elsewhere.

Tubes —The well consists of a hollow wrought-iron tube about $1\frac{1}{4}$ to 6 in diam., composed of any number of lengths, each of 3 to 10 ft., according to the depth required. The water is admitted into the tube through a series of holes, which extend up the lowermost length to a height of $2\frac{1}{2}$ ft. from the bottom. Specially tough lap-welded tubes are necessary, to withstand the hammering and vibration to which they are subjected, gas-pipe and other common brands are quite useless for this purpose

The essential part of the tube is the "point" *a* (Fig. 8), measuring about 3 ft. long, and perforated as already described. This is furnished at top with a socket *b* which receives the driving-cap *c*. Rigidly attached to this cap is

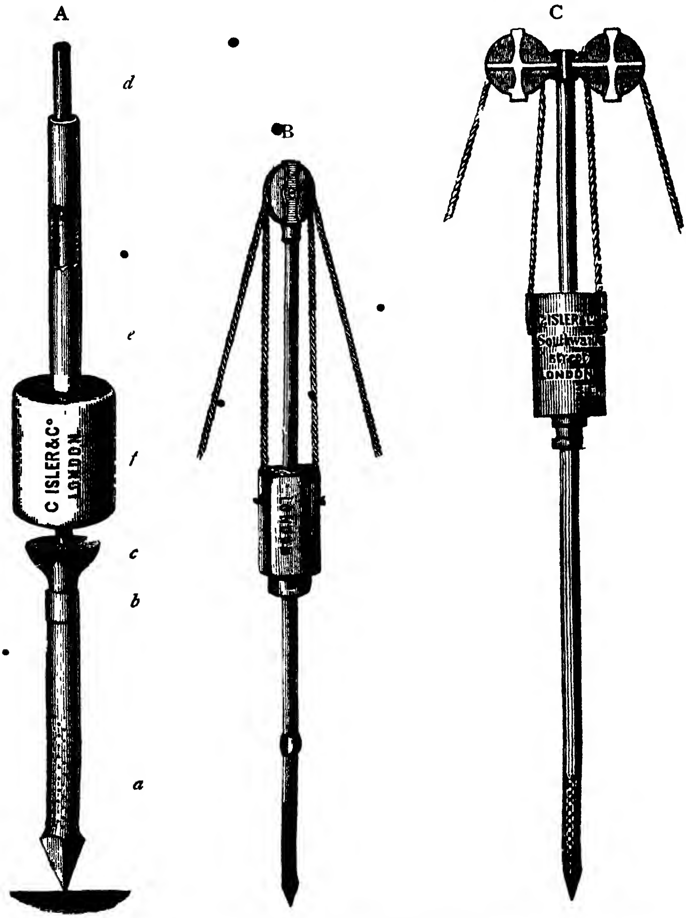


FIG. 8.—DRIVING TUBES.

a spindle or guide *d*, enveloped by the runner or sleeve *e* of the monkey or driver *f*. This method of applying the driving force to the tube is vastly superior to the old-fashioned system of a clamp fixed to the tube; the latter nearly always resulted in more or less indentation of the tube, sometimes causing much difficulty in adding new lengths. The monkeys may be raised by hand, as in A, or by ropes and pulleys as in B, C, B is the pattern used very extensively by the War Office.

Driving.—The spot for sinking having been chosen, a truly vertical hole is first made in the ground with a crow-bar, and in this the properly rigged tube is inserted, all joints having been first made quite tight When in position, two men raise the monkey either by hand (A) or by ropes (B, C). In the latter case, they should stand exactly opposite each other and equidistant from the tube, pulling the ropes at identical angles, and moving in time together, so that the tube may maintain a vertical position and follow a straight course Should it deviate at all, gentle pressure must be used to bring it gradually back, the pressure being applied to the tube itself, and not on any account to the spindle or guide-bar

The driving-cap must be tightened after every few blows.

Though two men suffice for driving a $1\frac{1}{4}$-in tube, an extra hand will make a great difference to the speed, as he can give undivided attention to the perpendicularity of the tube and add some impulse to the fall of the monkey.

It is most essential to see that the first length is driven quite vertically, the driving should therefore be conducted with the greatest care for the first 2 or 3 ft. The driving-cap is withdrawn when a few inches off the ground, and a fresh length of pipe is added. The pulley-bar and monkey must be removed to allow the driving-cap to be unscrewed.

As each joint on the tubes has to be water- and air-tight, it must be oiled and white-leaded before fixing the pipe on the length previously driven

The socket is removed from one end of the pipe whilst on the ground, by gripping the pipe with barrel-tongs, the foot being lightly placed on the handles, and the socket unscrewed by means of socket-tongs. The driving-cap is screwed to this length of pipe, the monkey and pulley-bar are slipped through it in the same manner as with the first length, and the whole is bodily raised and screwed to the tube driven It is most particularly to be noted that the smaller or barrel-tongs are to be used on the tube in all instances, whether to screw or unscrew joints, otherwise joints that have been made may get disturbed, and ruin the work The socket-tongs are placed on the socket, and the pipe is then screwed up tightly so that the joints butt against one another, length after length is in this manner added until the required depth is attained.

Clearing—The tube well should be sounded by means of the plumb-bob from time to time during the driving, to detect the presence either of water or of soil inside the tube. A certain amount of soil is sure to find its way in, and should be cleared at intervals, otherwise, if the accumulation be allowed to increase, springs may be passed, and remain undiscovered.

The "clearing-out tubes" are to be used for this purpose. Length after length is screwed together by means of ½-in barrel- and socket-tongs, and suspended by ½-in. clips 2 or 3 in. above the debris, so that they will not choke. Previous to lowering the ½-in tubes, the funnel (Fig. 9) should be screwed to the well-tube, and by this means water is poured into the well whilst it is being cleared A pump and reducing socket are attached to the ½-in. tubes,

and these are gradually lowered until the whole of the debris has been removed from the pipe, when the clearing-out tubes are withdrawn.

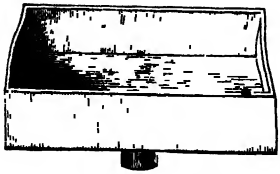


FIG. 9.—FUNNEL.

When it is found impracticable to clear the well with the ordinary point, recourse is had to "a sand-tube" (Fig 10), made according to the fineness of the sand to be dealt with. Its action is in every way similar to that of the ordinary well point; but it is protected by a perforated brass sheath fixed over the drilled part of the tube, and the holes in the pointed pipe are drilled very much larger than in the ordinary well-tube, to allow for the fine perforated brass. The tube well is driven and cleared in the usual manner by means of the ½-in. tubes, etc.

FIG 10. SAND-TUBE.

It will be found that, even in gravelly soils, tube wells will be made in much less time, both as regards clearing and pumping, if protected with a strainer.

Tilting.—As soon as the presence of water has shown itself to the extent of a few feet in the tube, the pump should be attached directly to the well-tube, care being taken to white-lead all the threads. The pump is started by pouring water into the top, to force the air from the pipe; if a supply exists, the water will soon

follow. It will be more or less muddy, according to the nature of the soil through which it is obtained.

The handle of the pump should be raised as high as practicable, to allow the valves to open. This will suddenly release the column of water held in the well-tube, which will instantly drop to its level, forcing its way through the perforations in the bottom length, and so disturbing the surroundings of the well. This action should be repeated over and over again, causing the water to be played in and out of the perforations, and thus allowing the finer particles to be pumped out and the larger to be gradually drawn around the well-tube, forming a natural filter, the operation is called "tilting," and should be discontinued when the water is practically free from grit. Disconnection is effected by loosening the studs which hold the ring to the pump-barrel, and giving the handle a quarter-turn, steady pumping should then take place for a short time, when it will be found that the water will become quite clear and free from sandy particles

The whole secret of making successful tube wells lies in the proper use of the pump. It is therefore necessary that the above instructions should be accurately followed—if neglected, the tube well may become choked, resulting in a total stoppage of the supply.

In close and compact soils, such as sand, gravel, chalk, etc, much patience and perseverance are required in developing supplies of water. The yield is at first scanty, but rapidly increases by the tilting of the pump, which helps to disintegrate the surrounding soil, and forms a free passage for the water.

Drawing.—It often occurs in driving that impervious or solid strata, such as thick beds of clay, rock, etc., are met with. In these cases, it is necessary to withdraw

the tube, which is accomplished in the following manner. The monkey is slipped over the well-pipe, the driving-cap is screwed above it to the well-tube, and the pulley-bar is again slipped into position, allowing the men to strike the monkey upwards against the driving-cap; thus the tubes are forced out of the ground. Other means are also adopted, such as bottle-jacks, or a hollow jack specially designed for this purpose. *The tubes, previous to being re-driven, should* be carefully examined, and, *if found* bent, must be discarded, unless they can be straightened at a forge or by striking them with the side of the monkey.

Depth.—The depth to which tube wells may be driven is entirely governed by the nature of the soil; they commonly reach 60 to 70 ft., and sometimes even 100 ft. or more. Yet in many cases an ordinary lift-pump may be employed on them, the water rising to within 28 ft of the surface, and often higher.

When it happens that an objectionable spring is tapped the tube is driven deeper in search of other springs. It is to be noted that the upper springs will not affect the lower ones when the latter are tapped.

Deeper Wells.—When the water is below lifting reach of the ordinary lift-pump, viz. 28 ft. from the surface, it is advisable to drive a larger tube well, as illustrated and described below.

Knowing the exact depth at which the water comes in, the proper length of tube is driven, and the working barrel (either made of steel or phosphor-bronze) is screwed to it, taking care to slip the valve-seat (*a*, Fig. 11) into position, so as to rest next to the well-pipe. The working barrel is so placed as to be within lifting reach of the water. All the joints must butt as in the case of the smaller well.

The ring *b* (Fig. 11) is placed on the top of the working

barrel when the next length of well-tube is butted to it; the driving is then continued to the depth required.

To remove the soil which has found its way into the tube well, a small shell with a valve is provided: this is attached to the $\frac{1}{2}$-in. tubes, and is lowered until it has reached the debris, when the whole is lifted up and down to allow all the soil to pass into the $\frac{1}{2}$-in. pipes, and to effectually clear the tube. The $\frac{1}{2}$-in. tubes are then with-

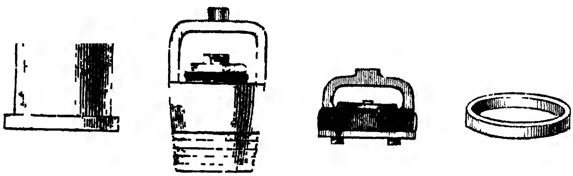


FIG. 11—DEEP WELL FITTINGS

drawn in 12-ft. lengths. This mode of clearing also applies to the ordinary tube well, and will be found far more expeditious than clearing it with the funnel (see page 13), which latter cannot be used for deep wells.

The taper end of the valve *c* (Fig. 11), is wound with tow, a little tallow and white-lead mixed being added to make it adhere. This will make a water-tight joint when fixed in the seating. The valve is lowered into its position by means of a hook or screw attached to the pump-rods, and, to ensure a water-tight joint, a few gentle blows are given on the top of the valve by means of the rods and hook. The rods are then withdrawn, the hook is disconnected, and the bucket *d* (Fig. 11) is screwed in place. The rods are lowered until the bucket has fairly entered the working barrel, when it is connected to the pump-rod, the whole being then ready to commence pumping. The pump-rods

D 2

are united by means of triangular couplings, secured by split pins.

Previous to working, the pump will need to be "primed" as usual by pouring water through the top, when a yield will soon follow. It is advisable to work the pump rather sharply at first to enable the finer particles to be drawn up.

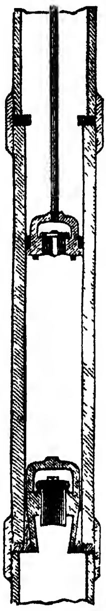


FIG 12
WORKING BARREL.

The arrangement of this deep-well pump is extremely simple, and should the pump require seeing to, through either the bucket or the valve getting out of order, the whole is withdrawn for examination in the same manner as it was fixed, without the necessity for disturbing the rising main or tube well.

Fig 12 illustrates the working barrel completely fitted with all its parts, and Fig. 13, the tube well with its deep-well pump in position.

It is to be observed that the instructions given for smaller wells are applicable also to deeper wells

Another method of dealing with deep wells when it is found that the water-level is below lifting reach, is to sink a hole so as to meet the water-level, and thus allow the ordinary pump to be fixed on the top of the tube well at the bottom of the sunken pit, and to be cleared by means of the ½-in. tubes, and "tilted" in the ordinary way to develop a supply, previous to fixing the deep-well pump. In this case (Fig 14) the tube well is smaller than the rising main of the pump, which may be of wrought-or cast-iron flanged pipe For example, suppose the tube well to be 70 ft from the surface with 30 ft. of

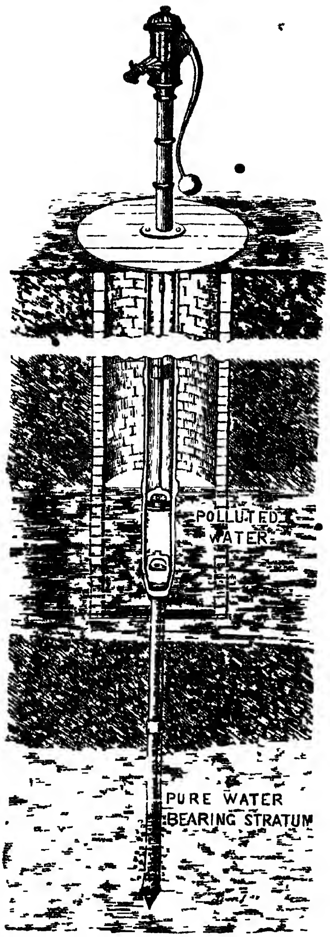


FIG 14.—TUBE WELL FROM DUG WELL

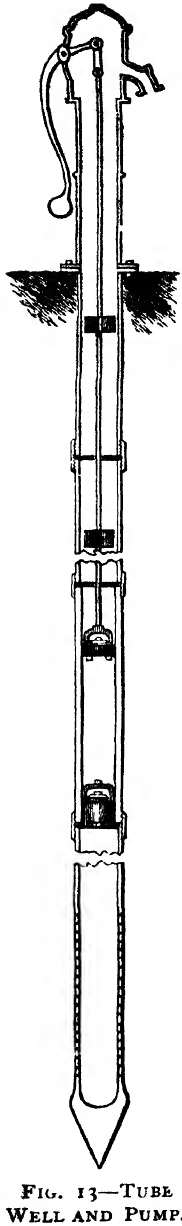


FIG. 13—TUBE WELL AND PUMP.

water in the well, the pit is sunk 15 ft., bringing the water-level from the bottom of the pit to 25 ft. When the permanent pump is fixed, the hole may be re-filled, but it is more advisable to "stein" it

By this means, dug wells can easily be deepened at a trifling outlay, and polluted sources be at the same time avoided.

Connecting Wells.—It frequently occurs that large supplies are required for towns, manufactories, irrigation, etc.

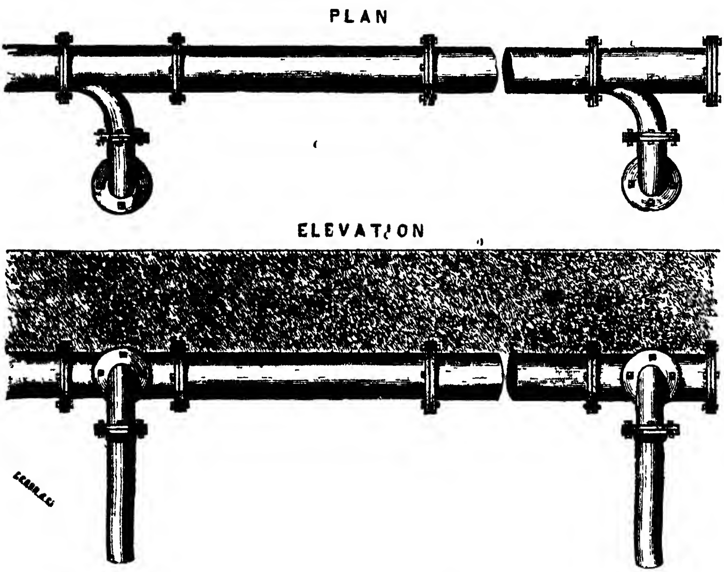


FIG. 15—CONNECTED WELLS.

To accomplish this, as many wells as necessary are connected, as illustrated in Fig. 15. In such cases it will be found far more economical to test each spot with the smallest well previous to fixing the permanent one, as the probable yield will thus be approximately ascertained, and

this will govern the number and size of wells required to furnish the supply wanted. Results obtained by this means will be found far more satisfactory and economical than by drawing from one point as with dug wells. Yields vary greatly with the nature of the strata, and it often occurs that a larger tube well will not increase the yield in proportion to a smaller one

The average quantities obtained from tube wells are as follows · 1¼-in., 500; 2-in., 1000, 3-in, 2000 gall per hour.

For transport purposes, the smallest well will be found in every way the least expensive. Tube wells can be coupled either by cast-iron flanged pipes with rubber joints or by wrought-iron socketted pipes, fitted with T-pieces and bends in the same manner as cast-iron. The whole of the rising main is laid in a trench 18-in. to 2 ft. under ground The distance which the wells should be placed apart generally varies from 15 to 18 ft., being to a great extent governed by the water-bearing stratum; there are cases where they may be nearer to one another without affecting the draught, but the figures given are a reliable average.

Costs.—The following details of prices for materials and work in sinking driven tube wells are taken from C Isler & Co's estimates —

MATERIALS ONLY.

1¼-in. well-tubing, 1*s* per ft.
,, 3-ft points, 10*s*. each
,, 3-ft sand-tubes, 20*s* each
,, tube-well apparatus (Fig 8), 5*l* 5*s*
,, ditto, with tools complete, 11*l*
,, tube-well apparatus (tripod pattern), 6*l*
,, ditto, with tools complete, 12*l*
2-in well-tubing, 2*s* per ft.
,, 3-ft. points, 20*s* each.
,, 3-ft. sand-tubes, 28*s*. each.
2-in tube-well apparatus (Fig 8) 6*l* 6*s*.
,, ditto, with tools complete, 16*l*
,, tube-well apparatus (tripod pattern), 7*l* 7*s*
,, ditto, with tools complete, 17*l*.
3-in well-tubing, 3*s* 6*d* per ft.
,, 3-ft. points, 38*s* each.
,, 3-ft. sand-tubes, 58*s* each.
,, tube-well apparatus, complete with all tools and sheer-legs, 31*l*.

Hand-Pumps for Tube Wells.

Common Pitcher Spout	Strong Pitcher Spout	Standard, with Valve Door
3-in. barrel, 18*s*.	3-in. barrel, 28*s*	3-in barrel, 55*s*.
4 ,, ,, 22*s*.	4 ,, ,, 33*s*	4 ,, ,, 75*s*.
6 ,, ,, 68*s*.		

Materials and Well-Driver's Time

		£	*s*	*d.*			£	*s.*	*d.*
1¼-in.	12 ft deep	2	3	6	1¼-in	27 ft deep	4	6	0
,,	15 ,,	2	12	0	,,	30 ,,	4	14	6
,,	18 ,,	3	0	6	,,	33 ,,	5	3	0
,,	21 ,,	3	9	0	,,	36 ,,	5	11	6
,,	24 ,,	3	17	6	,,	39 ,,	6	0	0

Beyond this depth 2*s* 10*d* per ft., 3-ft galvanised points (18*s*), sand-strainer (15*s*), and pumps extra.

	£	*s*		£	*s*.
12 ft deep	4	0	27 ft. deep	7	15
15 ,,	4	15	30 ,,	8	10
18 ,,	5	10	33 ,,	9	5
21 ,,	6	5	36 ,,	10	0
24 ,,	7	0	39 ,,	10	15

Beyond this depth, 5*s* per ft, 3-ft galvanised points (35*s*.), sand-strainer (25*s*), and pumps extra

		£	*s*.			£	*s*
3-in.	12 ft. deep	7	0	3-in	27 ft. deep	15	0
	15 ,,	9	10		30 ,,	16	10
	18 ,,	10	10		33 ,,	18	0
	21 ,,	12	0		36 ,,	19	10
	24 ,,	13	10		39 ,,	21	0

Beyond this depth, 10*s* per ft, 3-ft galvanised points (3*l*), sand-strainer (35*s*), and pumps extra

Testing localities, 20*s* per diem.

CHAPTER IV.

BORED TUBE WELLS

Scope—When hard ground or solid rock is encountered, through which the cutting point or edge of tube cannot be forced with reasonable facility and speed, a way must be made for the tube by boring a hole and removing the debris in advance of the tube, either by percussion (which churns up the rock to powder or mud) or by diamond or calyx drilling (which cuts out a solid core)

Early Methods—The first method of well-boring known in Europe was that called the Chinese, in which a chisel, suspended by a rope and surrounded by a tube a few feet long, is worked up and down by means of a spring-pole or lever at the surface. The twisting and untwisting of the rope prevents the chisel from always striking in the same place; and by its continued blows the rock is pounded and broken. The chisel is withdrawn occasionally, and in its place is lowered a bucket or shell-pump, having a hinged valve at the bottom opening upwards, so that a quantity of the debris becomes enclosed in the bucket, and is drawn up by it to the surface. The lowering of the bucket is repeated until the hole is cleared, and the chisel is then put to work again

In Fig. 16 is shown an apparatus on the Chinese system; it may be used for either hemp-rope or wire-rope, and was originally made for hoop-iron. At A is a log of oak, set perpendicularly so deep in the ground as to pene-

trate the loose gravel and pass a little into the rock, standing firmly in its place; it is well rammed with gravel, and the ground is levelled so that the butt of the log is flush with the surface of the ground or a little below it. Through this log, which, according to the depth of loose ground, may be 5 to 30 ft. long, a vertical hole is bored by an

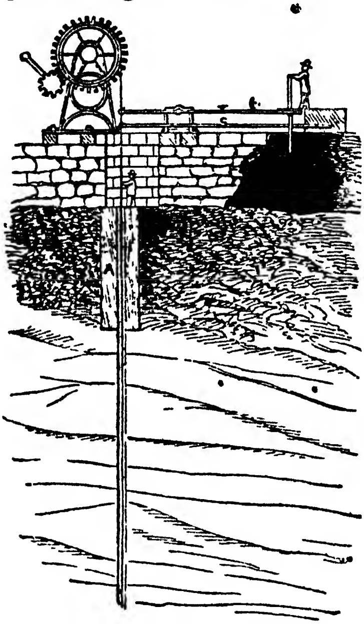


FIG. 16.—CHINESE BORING.

auger of a diameter equal to that of the intended boring in the rock On top of the ground, at one side of the hole, is a windlass whose drum is 5 ft. diam., the cog-wheel which drives it is 6 ft., and the pinion on the crank-axle is 6 in. This windlass serves for hoisting the spindle or drill, and is of large diameter to prevent short bends in the iron (which would soon become brittle) and to prevent permanent bends.

On the opposite side of the windlass is a lever of unequal leverage, about one-third at the side of the hole, and two-thirds at the opposite side, where it ends in a cross or broad end when men do the work. The workmen, with one foot on a bench or platform, rest their hands on a railing, and work with the other foot the long end of the lever In this way the whole weight of the men is made use of. The lift of the bore-bit is 10 to 12 in., which causes the men to work the treadle 20 to 24 in. high Below the treadle T is a spring-pole S, fastened under the platform on which the men stand, the end of this spring-pole is connected by a link to the working end of the lever, or to the rope directly, and pulls the treadle down When the bore-spindle is raised by means of the treadle, the spring-pole imparts to it a sudden return, and increases by these means the velocity of the bit, and consequently that of the downward stroke.

Modern Methods—This rudimentary system, adapted to out-of-the-way localities, and where human labour is cheaper than machinery, is now seldom seen, having given place to much improved percussive mechanism, and to a most ingeniously-contrived variety of tools for coping with the constant changes of strata.

Tools.—In Figs 17, 18 and 19 are exhibited a selection of up-to-date well-boring tools, *a* is an auger for clays and stiff soils; *b*, a worm-auger for loosening gravelly and sandy soils, *c*, flat-bladed chisel, *d*, flat V chisel, *e*, flat T chisel; *f*, T V chisel, *g*, X chisel, all these chisels being for cutting through solid strata, *h*, circular chisel for trimming bore-hole true and vertical, *i*, spring chisel for enlarging bore-hole below pipes, *j*, "shell" for removing debris cut by the chisels, *k*, worm-nose shell for loose soils; *l*, water shell for testing supply preparatory to doing so by means

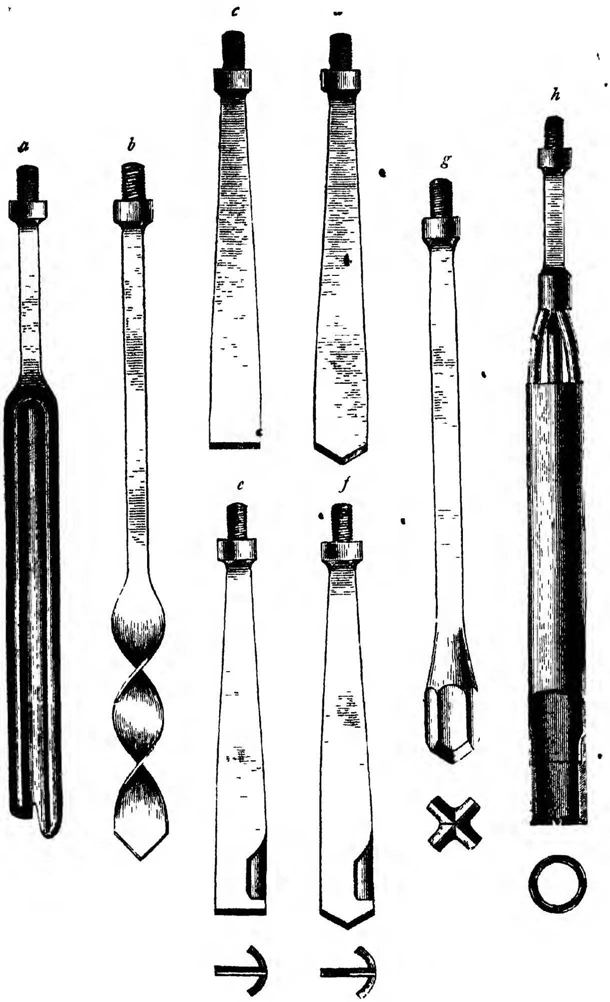


FIG. 17.—WELL-BORING TOOLS

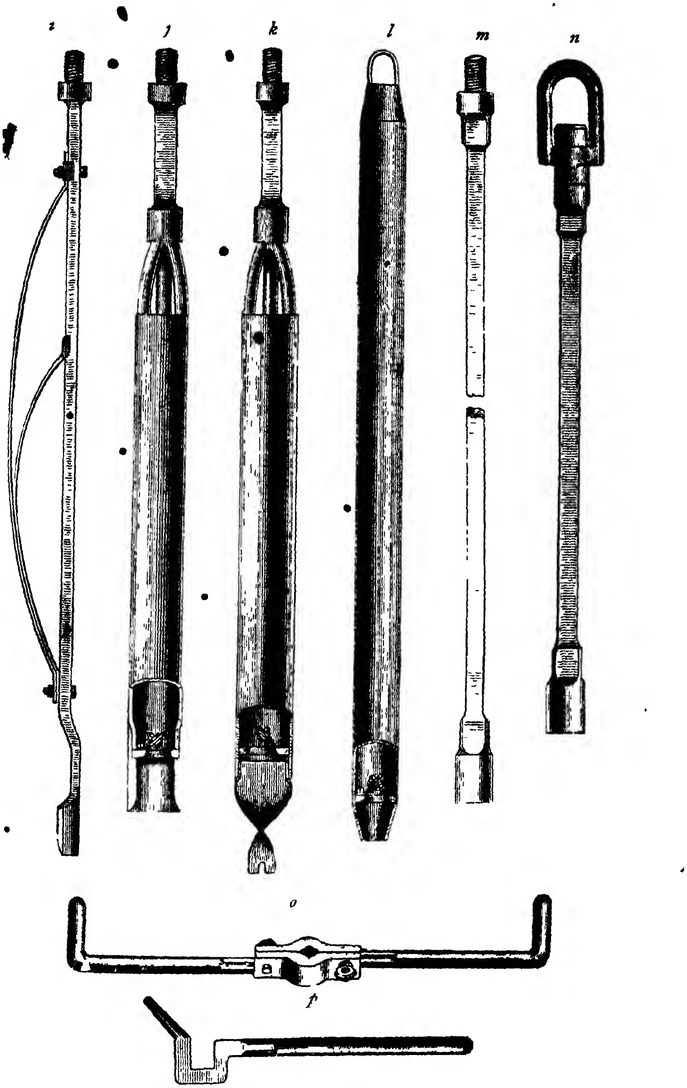


FIG 18.—WELL-BORING TOOLS.

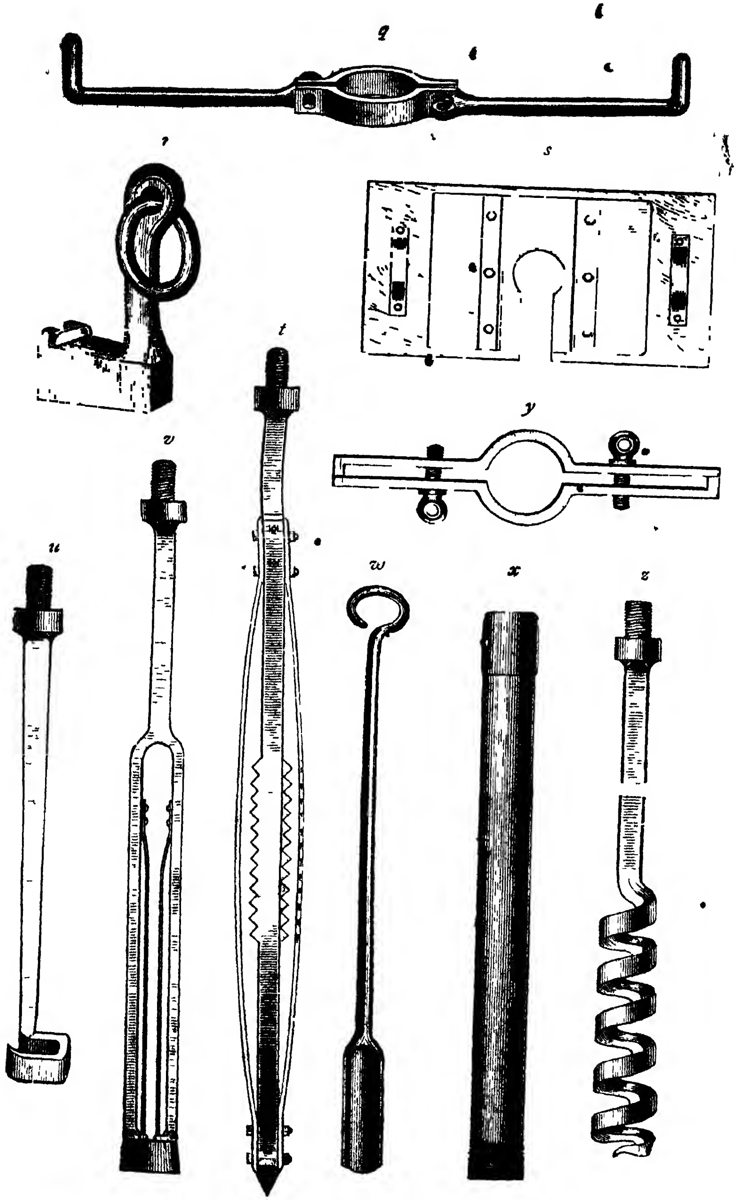


FIG. 19.—WELL-BORING TOOLS.

of a pump, when the water-level is below 30 ft. from surface; *m*, boring-rod; *n*, swivel-rod; *o*, tillers for turning rods; *p*, hand-dog for screwing rods, with taper end for tightening tiller-screws, *q*, tillers for screwing and turning pipes; *r*, dog for lowering and withdrawing rods; *s*, auger-board for holding lifting-dogs while screwing and unscrewing rods, *t*, spring rimer for enlarging bore-hole below pipes, *u*, crow's-foot for recovering broken rods; *v*, bell-box for recovering broken rods when the top joint is left on; *w*, cleaner for augers and shells; *x*, steel socketted tube, *y*, clamps for screwing tubes together and suspending them from pipe stage, *z*, worm for recovering broken tools.

Chisels are made from wrought iron or mild steel, and when small are usually 18 in long by 2½ in. extreme breadth, and weigh some 24½ lb., the cutting edge is faced with best steel Whilst in operation they need careful watching, that they may be removed and fresh tools substituted when their edges are sufficiently worn to diminish their breadth. If this is not attended to, the size of the hole decreases, so that, when a new chisel of the proper size is introduced, it will not pass down to the bottom of the hole, and much delay is occasioned in enlarging it. In working with the chisel, the borer keeps the tiller or handles in both hands, one upon each, and moves slowly round the bore, in order to prevent the chisel from falling twice successively in the same place, this helps to preserve the bore circular Every time a fresh chisel is lowered to the bottom, it should be worked round in the hole, to test whether the proper size and shape have been maintained; if this is not the case, the chisel must be raised at once, and be worked gradually and carefully until the hole is as it should be. The description of strata being cut by the chisel can be detected

with considerable accuracy by a skilful workman from the character of the shock transmitted to the rods Should the stratum be very hard, the chisel may be worn and

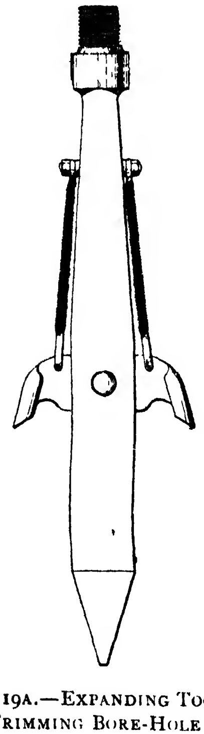


FIG. 19A.—EXPANDING TOOL FOR TRIMMING BORE-HOLE BELOW TUBES

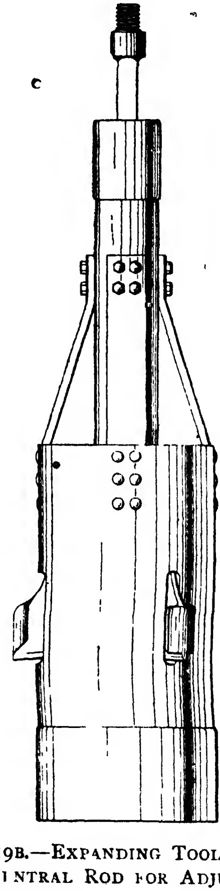


FIG. 19B.—EXPANDING TOOL WITH CENTRAL ROD FOR ADJUSTING CUTTERS.

blunted before cutting $\frac{3}{4}$ in, hence it must be frequently raised and examined, but 7 or 8 in may be bored without examination when the nature of the stratum follows

Augers are often 10 ft. long, 3 to 3½ ft. of which is shell.

Boring-rods are in 3-, 6-, 10-, 15-, or 20-ft lengths of wrought iron or mild steel, preferably Low Moor or mild steel, and generally 1 in. to 3 in. square in section; at one end is a male and at the other end a female screw for the purpose of connecting them together. The screw should not have fewer than 6 threads, as the female screw frequently splits, and the screw may have its thread so worn as to become liable to slip. Rods should be carefully examined every time they are drawn out of the bore-hole, as an unobserved failure may occasion much inconvenience, and even the loss of the hole. In addition to the ordinary lengths of rod, short pieces varying from 6 in. to 2 ft. are required for adjusting the rods at a convenient height.

When a projection in the bore-hole obstructs the downward course of the lining tubes, the hole is enlarged below the pipes by means of the spring rimer *t*. It consists of an iron shank, to which two thin strips are bolted, bowed out in the form of a drawing-pen. The rimer is screwed on to the boring-rods, and forced down through the pipes; when below the last length of pipe, the rimer expands, and can then be turned round, which has the effect of scraping the sides and enlarging that portion of the hole subject to its operation.

Rigs.—Some means of suspending the tackle from which the rods are hung, as also of obtaining a lift for them, must be provided. Triangle gyns are sufficient for light work, whilst for that of a heavier character sheers, derricks, or massive sheer-frames are requisite.

In England, for small works, the entire boring apparatus is frequently arranged as in Fig. 20, the tool being fixed at the end of wrought-iron rods instead of at the end of a rope,

as in the Chinese method. A is the boring tool; B, rod to which the tool is attached; D, levers whereby men E give a rotary motion to the tool; F, chain for attaching

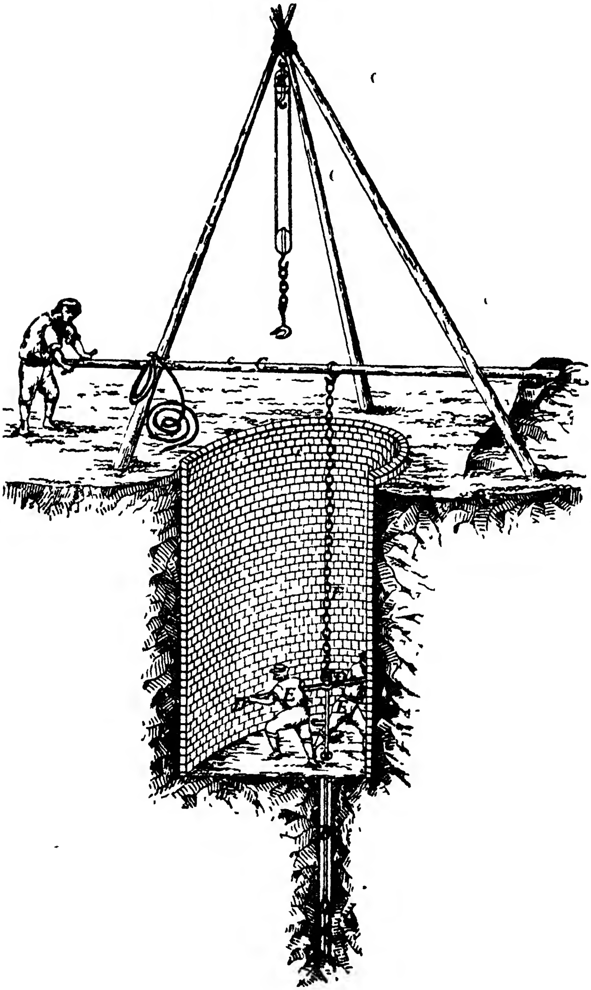


FIG. 20.—A BORING RIG.

boring apparatus to pole G, which is fixed at H, and by means whereof the man on surface transmits a vertical motion to the tool when necessary.

The sheer-legs, made of sound Norway spars not less than 8 in diam. at the bottom, are placed over the bore-hole for the purpose of supporting the tackle for drawing the rods out of and lowering them into the hole. It is obvious that the more frequently it is necessary to break the joints in drawing and lowering the rods, the more time will be occupied in changing the tools, or in each cleaning of the hole, and as the depth of the hole increases, the more tedious will the operation be. It therefore becomes a matter of much importance that the rods shall be drawn and lowered as quickly as possible, and to attain this end as long lengths as practicable must be drawn at each lift The length of the lift or off-take, as it is termed, depending altogether upon the height of the lifting tackle above the top of the bore-hole, the length of the sheer-legs for a hole of any considerable depth should not be less than 30 to 40 ft., and they usually stand over a small pit or dug well, which may be sunk, when the ground is dry, to a depth of 20 or 30 ft From the bottom of this pit the bore-hole may be commenced, and here will be stationed the man who has charge of the bore-hole while working the rods.

Fig 21 shows another plan of commencing a boring. Here *a* are foot-blocks for the legs of the gyn, *b*, rope shackle, *c d*, staging; *e*, guide-block. A pit lined with timber or masonry is sunk 10 or 12 ft. in the clear, and below this is a smaller pit 6 ft. square by 5 ft. deep, also lined. Above these the sheer-legs are erected so that the rope when passed round the wheel at top may hang over the centre of the pits. The top of the lower part is covered, all except a gap of 9 in. in the centre, with loose planks to

form a stage; the two middle planks are 3 to 4 in. thick, as they may have to carry an auger-board, and sustain the whole weight of the rods.

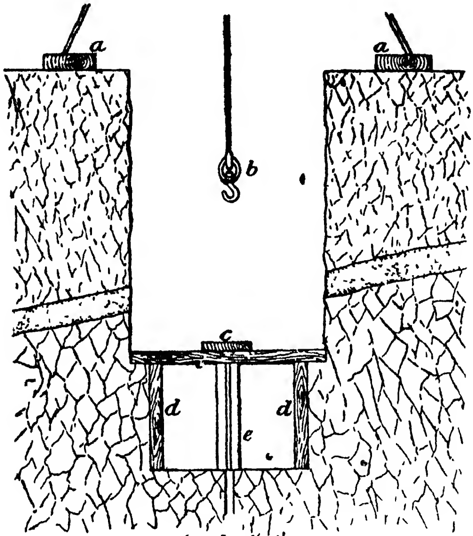


FIG. 21 —COMMENCING A BORE

The arrangement in Fig. 22 is intended for deep or difficult boring with rods A regular scaffolding is erected, upon which a platform is built. The boring-chisel A is, as in the last instance, joined by means of screw couplings to the boring-rods B At each stroke, 2 men stationed at E turn the rod slightly by means of the tiller D. A rope F, which is attached to the boring-tool, is passed a few times round the drum of a windlass G, the end of the rope being held by a man at I. When the handles are turned by the men at L, the man at I pulls at the rope; the friction between the rope and the drum of the windlass is then sufficient to raise the rods and boring-tool. As soon as the

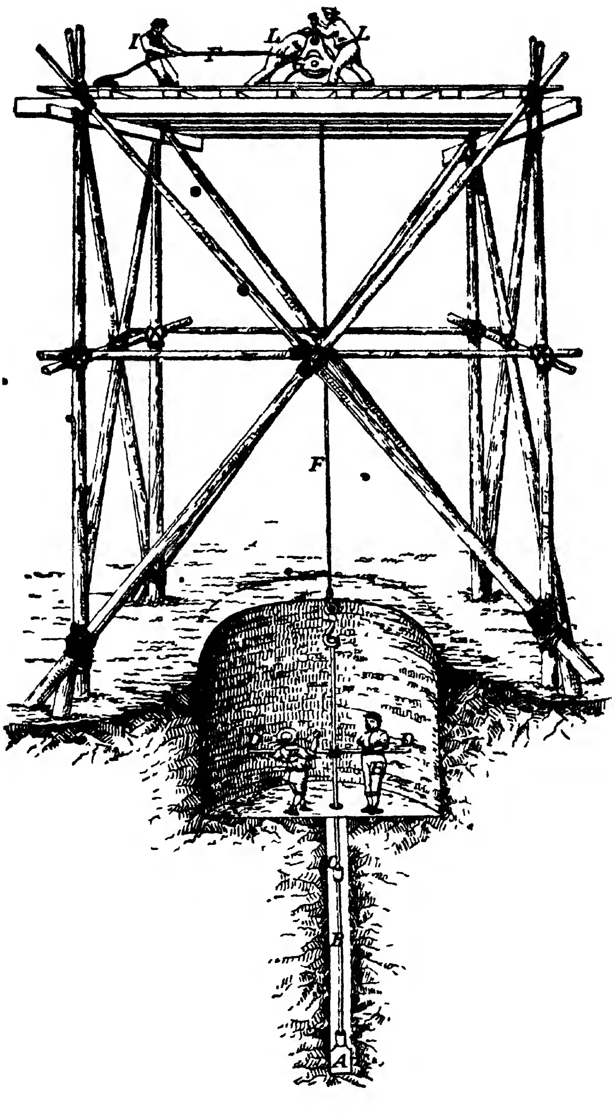


FIG. 22.—A BORING RIG

tool has been raised to its intended height, the man at I slackens his hold upon the rope, and as there is insufficient friction on the drum to sustain the weight of the boring-tools, they fall. In due course, the tiller is unscrewed, and a lifting-dog, attached to the rope from the windlass, draws up the rods as far as the height of the scaffolding or sheer-legs will allow, when a man at E, by passing a hand-dog or key upon the top of the rod under the lowest joint drawn above the top of the hole, takes the weight of the rods at this joint, the men at L having lowered the rods for this purpose ; and with another key, the rods are unscrewed at this joint, the rope is lowered again, the lifting-dog is put over the rod, another rod is screwed on, the rods are lifted, and the process is continued till completion.

Sometimes, if the hole is very dry, a little water poured down assists the work, but, if the hole is still unpiped, care is necessary not to wash away the sides.

When a deep boring is undertaken, direct from the surface, the operation had best be conducted with the aid of a boring sheer-frame such as is shown in Fig. 23 This consists of a framework of timber balks, upon which are erected four standards, 27 ft. high, 12 × 9 in thick, 3 ft. 8 in. apart at the bottom and 1 ft. 2 in. at top. The standards are tied by cross-pieces, upon which are cut shoulders that fit into mortice-holes ; they are fastened by wooden keys, the standards being surmounted by two head-pieces 5 ft long, mortised and fitted Upon the head-pieces two independent cast-iron guide-pulleys are arranged in bearings, over these pulleys are led the ends of two ropes coiling in opposite directions upon the barrel of a windlass, this is moved by spur gearing, and has a ratchet-stop attached to a pair of diagonal timbers, connected with the left-hand legs or standards of the sheers, near the ground. These ropes are used for raising and lowering the lengths of boring-rod.

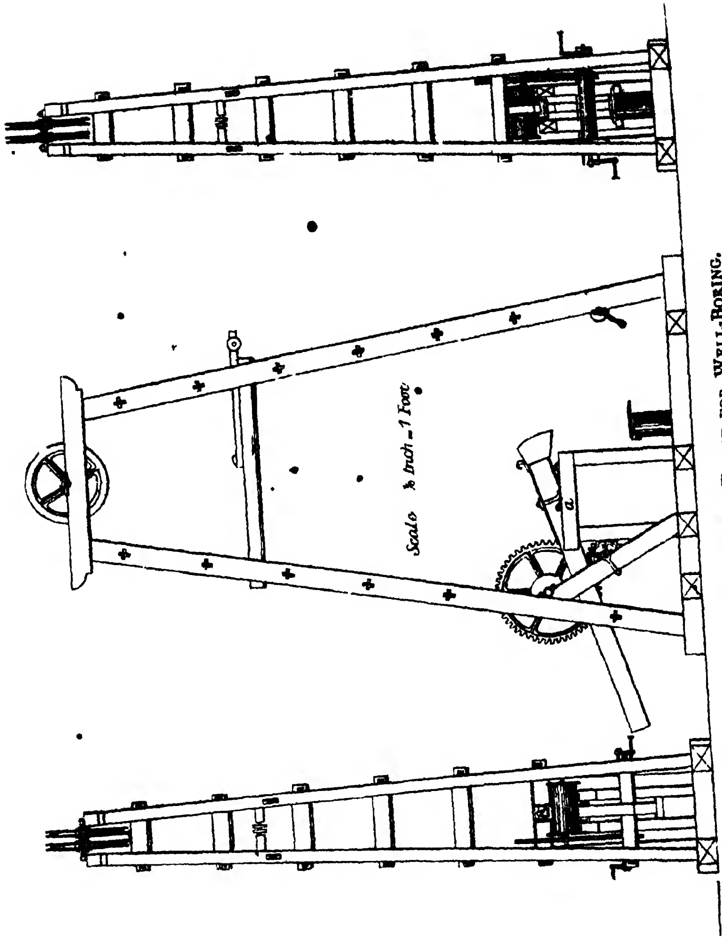


FIG. 23.—SHEER-FRAME FOR WELL-BORING.

At 8 ft. below the bearings of the top pulleys, a pair of horizontal traverses are fixed across the frame, supporting smaller pulleys, mounted on a cast-iron frame which is capable of motion between horizontal wooden slides. Over these pulleys is led a rope from a plain windlass fixed to the right-hand legs of the frame, to be used for raising and lowering the shell to extract the rubbish from the hole.

The lever, 15 ft. long and 9 × 6 in. in section, is supported by an independent timber frame It has a cast-iron cap, fastened by means of two iron straps, with lugs through which bolts are passed, these being tightened with nuts in the ordinary manner The bearing pins at *a* are 1½ in. diam., and also form part of the lower strap. Upon the cap is an iron hook; to this is attached a chain carrying a spring-hook which bears the top shackle of the rods The top of the bore-hole is surrounded by a wooden tube 1 ft. diam, provided with a hinged valve, whose action is similar to that of a clack-valve, this has a hole in the centre for the rods to pass up and down freely The valve permits of the introduction and withdrawal of the tools, while preventing anything from falling into the bore-hole. The lever is applied by pressure upon its outer end, and as the relation of the long to the short arm is as 4 to 1, a depression of 2 ft. in the one case produces an elevation of 6 in. in the other this is the minimum range of action, the maximum being 26 in

The modern tendency is towards rigs which, while retaining all necessary strength, are much lighter and therefore more portable, as well as being more cheaply, easily, and speedily mounted and dismounted. Some examples of standard patterns used by C Isler & Co. are shown in Figs 24 to 27 It will be seen that reliance is placed on wrought-iron tubular structure throughout. Fig. 24 is

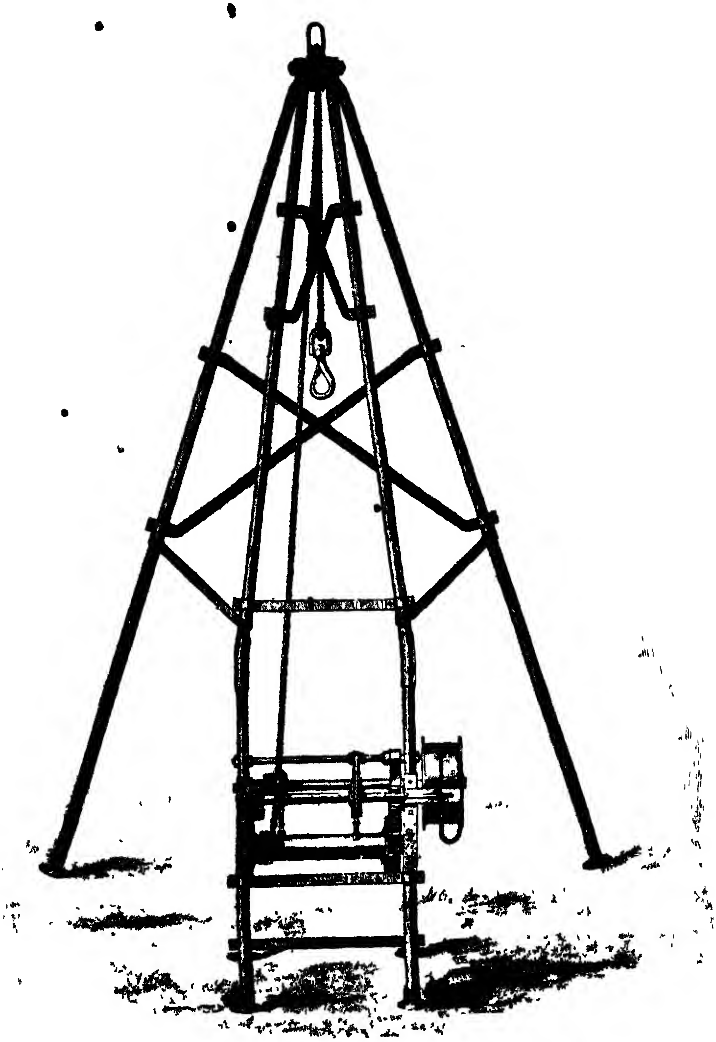


Fig. 24.—Sheer-Legs and Windlass

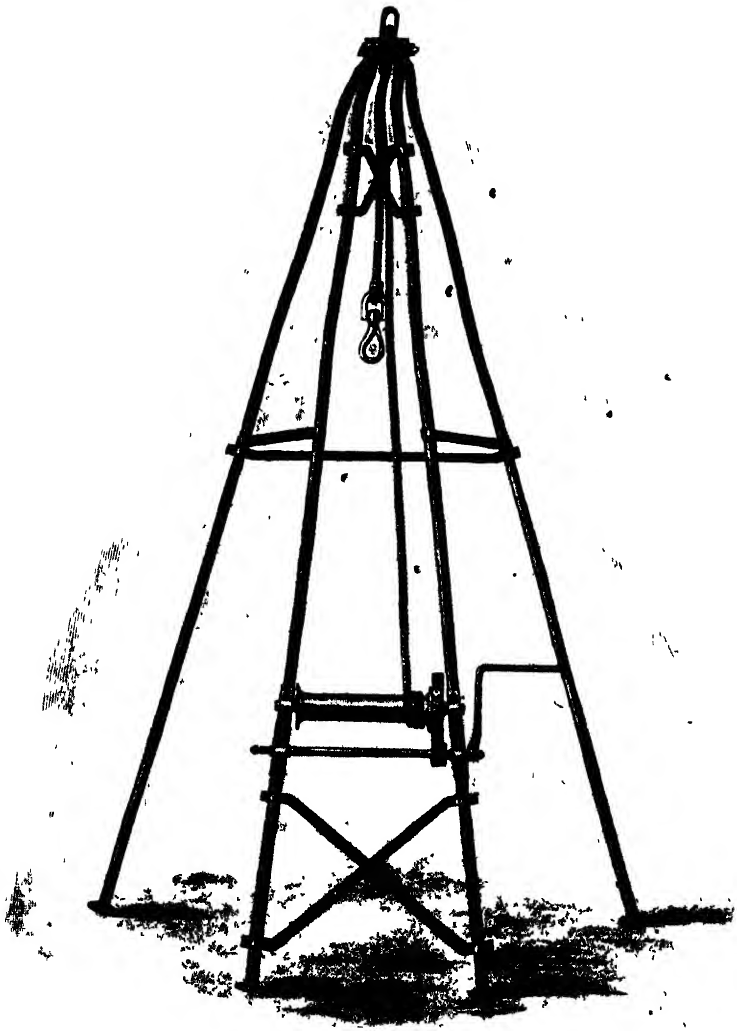


FIG. 25.—SHEER-LEGS AND WINDLASS

double-geared, with handles for manual operation and fast and loose pulleys for power. Fig. 25 is a lighter gear for hand-power only. In Fig. 26, a double-purchase crab-winch

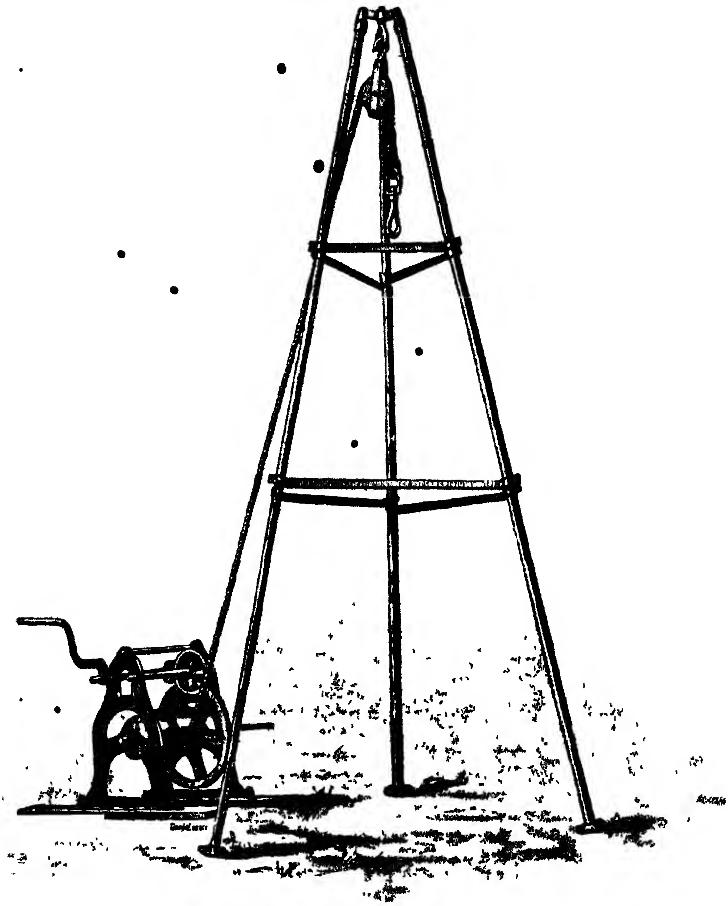


FIG. 26—SHEER-LEGS AND CRAB-WINCH

is mounted independently of the sheer-legs. Fig. 27 illustrates a more pretentious plant actuated by a small steam-driven winding-engine.

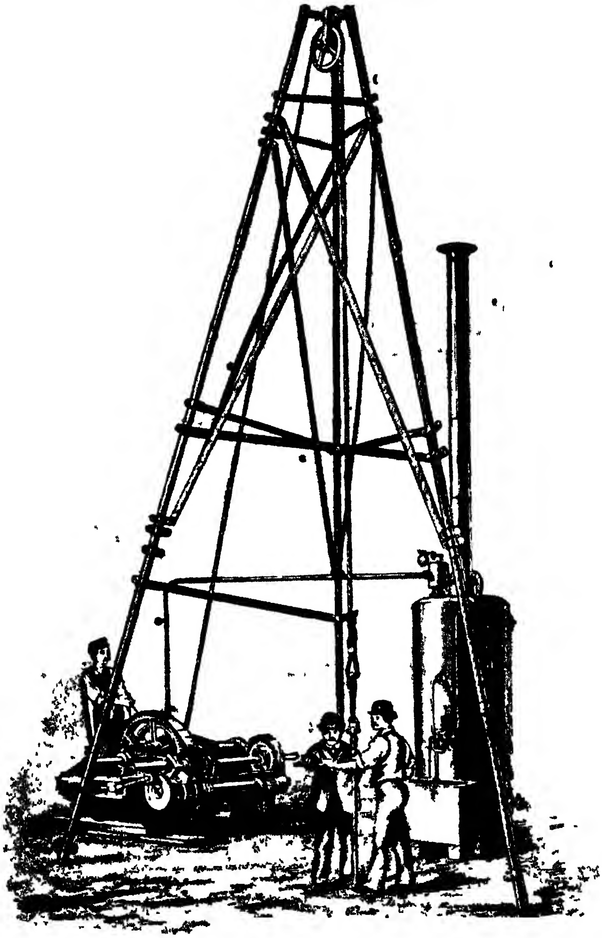


FIG. 27 —SHEER-LEGS AND STEAM-WINCH

Operations.—When, in the progress of operations, it is found that the tool refuses to drop to the same depth from which it has just been withdrawn, the employment of tubing becomes necessary This entails enlarging the hole already bored, by application of a rimer , and when this is accomplished down to the required depth, the first length of tube is inserted, following with successive lengths, each properly screwed to its predecessor, until the bottom of the hole is reached The boring tool is again rigged and operated inside the tubing , after boring a few feet deeper, another pipe may be screwed on, and the whole be driven farther down

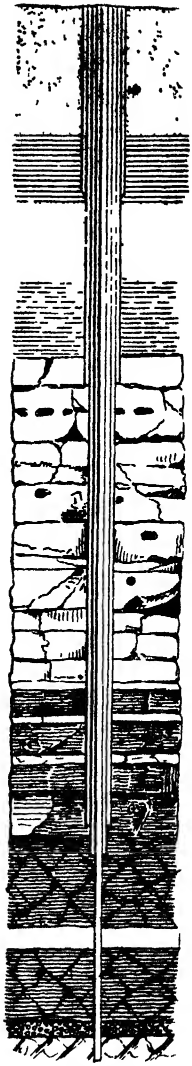


FIG. 28

If the thickness of soft stratum is very great, friction of the pipes, caused by pressure of the strata, may be such that perhaps not more than 80 or 100 ft can be driven without the pipes being injured. It will then be necessary to put down the first part of the hole with a large tool, and to drive in pipes of larger diameter , the hole is continued of smaller diameter, and lined with smaller tubes projecting telescope-fashion beyond the large tubes, as in Fig. 28, until the necessity for their use ceases

It will be evident that to ensure success the tubing must be truly

cylindrical and straight, and have a flush surface both outside and in. It will also appear that the thickness ought to bear a due proportion to the work required, and to the force likely to be used in screwing or driving it down. The first or bottom pipe is furnished with a steel shoe having a chisel-edge, and serves to trim the hole and cut a passage. The first length of pipe is raised by means of a pipe hanger, and lowered into the bore-hole until its top reaches about 1 ft above the surface; here a pair of pipe-clamps are securely fastened round it a few inches above the thread, and then the pipe is lowered until the clamps rest upon the board surrounding the top of the hole. The hanger is removed and screwed to a fresh length of tubing; this in its turn is lowered, and screwed quite home—until the two pipes butt together. The tillers being taken off, the whole length of tubing is raised a few inches, and suspended whilst the clamps are removed from the lower part. There are now two lengths of pipe, which are allowed to descend as before, when they are sufficiently deep, the clamps are re-applied, and the operation is repeated with each length screwed on.

Each joint should be oiled and screwed together with white or red lead, spun yarn is not needed.

While being lowered, the pipes are turned, particularly when they begin to hang up, in order that the steel shoe may remove any projections in the bore-hole.

When the pipes have been lowered to the necessary distance, and the pipe-clamps have been screwed on to secure them from slipping, boring can be resumed with the smaller-sized tools, after lowering the shell to bring up any debris caused through lowering the tubing.

When the tubing will not go down freely, the rimer may be employed if the stratum is not too hard. It is

screwed on to the bottom rod. As the springs measure the outside diameter of the tubing, they require to be pressed so as to force them through, but when once well in the pipes, the weight of the rods should be sufficient to carry them down. As soon as the springs are below the lowest length of pipe, they expand to their full size; and by turning the rods until the springs work quite freely, and lowering the rimer a little as they are freed, the hole below the tubing is cut out. Using the rimer is an operation requiring great care and attention.

When the rimer has been withdrawn, the pipes are attached and lowered as before.

The tubing should be turned as long as it will move

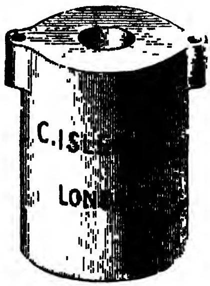


FIG. 28A.—MONKEY

FIG. 28B.—DRIVING-FLANGE.

before resorting to driving. It is advisable to use the longer lengths of pipe first, reserving the shorter lengths to the last, when the tubing will be going down more slowly. A long length standing up at a time when it becomes necessary to lower tools for clearing or enlarging below the tubing may seriously obstruct the work. Sometimes a short length of pipe may be used temporarily with advantage, a few feet of the descent being proceeded with, and then a longer length can be substituted as soon as the

boring has progressed sufficiently for a further lowering of pipes.

When it is found necessary to drive tubes, fix the driving-flange (Fig. 28B) by screwing it shoulder to shoulder to the top of the tube The monkey (Fig. 28A) with guide-*bar, is lifted into position and the driving is* proceeded with. This is done in the same way as "punching" with the tools as described below, with the exception that the spring hook is slipped through the rope sling on the monkey.

FIG. 28C.
STEEL SOCKETTED TUBE

The success of the well-work depends on practical experience and soundness of lining tubes The lining tubes should really be the first consideration, as employing an inferior tube means total collapse of the well—if not immediately, soon after completion.

The lining tube commonly and generally used, viz. a flush-jointed pipe, cannot stand any substantial strain such as these pipes have to bear during driving; and what occurs too often is the stripping or bursting of the joints, thereby causing utter failure, through creating a communication between the upper and lower part of the boring.

FIG 28D
STEEL SHOE

The lining tube recommended (Fig. 28C) is only of recent introduction, and supersedes all other kinds for the same purpose. It is of steel, as also is the socket which connects the pipes, allowing greater strength to be obtained in less substance, this, combined with the slight

setting in at the joints, practically renders the pipes flush outside as well as inside. When connected, they butt, leaving no space whatever between; by this means they form a solid joint, and it is therefore impossible for any of the joints to be otherwise than air and water tight, and is a secure preventive against any percolation from surface or objectionable springs

PRICES OF WROUGHT-IRON LAP-WELDED STEEL-SOCKETED TUBES.

3 in internal diameter,	¼ in	thick	4*s*	per foot.
4	,,	,,	5*s*.	,,
5	,,	,,	7*s*	,,
6	$\frac{5}{16}$	,,	10*s*	,,
7½	,,	,,	13*s*	,,
8½	,,	,,	17*s*.	,,
10	⅜	,,	20*s*	,,
11½	,,	,,	25*s*	,,

To withdraw broken or defective tubing quickly, two hooks attached to ropes are lowered down from opposite sides of the bore-hole, and caught on the rim of the lowermost tube, power is applied to haul the tubing up bodily.

Another most effective method for withdrawing broken or defective tubes is by a special expanding wedge tool, which enables pipes to be withdrawn by means of either the hydraulic or screw jack, as illustrated It may, however, be said that during our thirty years' experience we have met with practically no mishaps with broken or defective tubes. Accidents happen mostly with flush-jointed or rivetted tubes.

An effective method of cutting out lining-tubes practised in the United States consists in lowering into the bore-hole an expanding cutter-head, in which the circular cutters are first tightened, and then put into action by turning the boring-rods at surface.

To reduce stoppages for withdrawal of debris the Fàuvelle system was introduced, whereby the injection of a current of water through a central tube washes out the debris created by the cutting tool at the bottom. It has

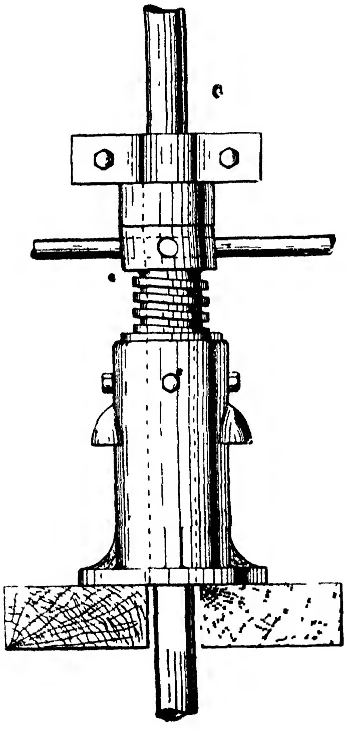


FIG 28F.—HOLLOW JACK FOR WITHDRAWING TUBES.

answered tolerably well when applied to shallow borings but the quantity of water required to keep the boring-tool clear is a great objection, especially as in the majority of cases wells are bored in places lacking a large supply.

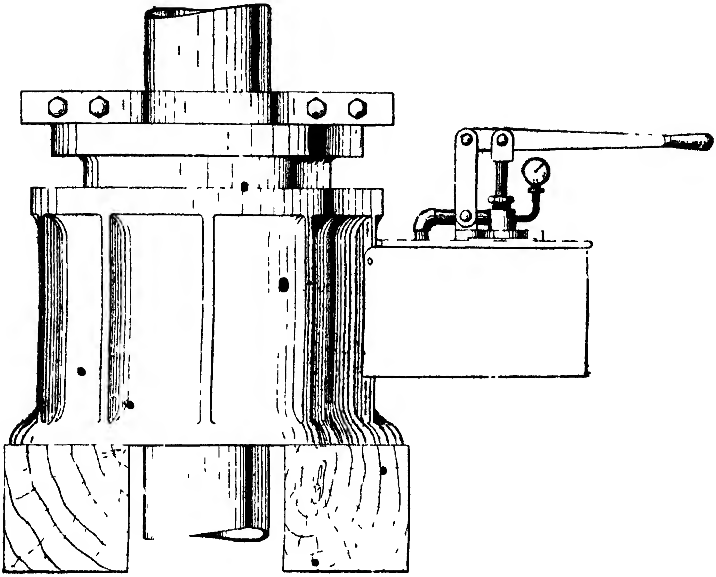


FIG. 28F.—C. ISLER & CO.'S IMPROVED HOLLOW HYDRAULIC JACK FOR WITHDRAWING LARGE TUBES.

Following are approximate prices for borings from the surface from 3 to 12 in. diam., exclusive of lining tubes and including all labour and necessary plant.

BORING IN GRAVEL, CLAY, SAND, CHALK OR OTHER SOFT STRATA

Not exceeding 100 ft	8s. to 20s. per ft.
,, 200 ,,	13s. ,, 30s. ,,
,, 300 ,,	18s. ,, 40s. ,,
,, 400 ,,	23s. ,, 50s. ,,
,, 500 ,,	28s. ,, 60s. ,,

BORING IN ROCK OR STONE, ACCORDING TO SIZE AND NATURE OF STRATA

Not exceeding 100 ft	20s. to 40s. per ft
And not less than 200 ft	25s. ,, 50s. ,,
,, 300 ,,	30s. ,, 60s. ,,
,, 400 ,,	35s. ,, 70s. ,,
,, 500 ,,	40s. ,, 80s. ,,

This does not include the cost of tubing, conveyance of plant and tools, professional superintendence, or working in rock of unusual hardness. A clause is usually inserted in the contract, to the effect that, if any unforeseen difficulty is met with in the course of the work, it is then paid for by the day, at a rate previously determined upon, until the difficulty has been overcome.

The following estimates for sets of boring tools are supplied by C. Isler and Co

(*a*) To bore 30 ft.—Two $2\frac{1}{2}$-in. T-chisels, one $2\frac{1}{2}$-in. flat chisel, one 2-in. shell, one 2-in. auger, one auger-board, one pair rod-tillers, two $\frac{3}{4}$-in. lifting-dogs, two $\frac{3}{4}$-in. hand-dogs, one spring-hook and rope, five 5-ft by $\frac{3}{4}$-in. boring-rods, one 5-ft. by $\frac{3}{4}$-in swivel-rod . . . . 12*l.* 10*s.*

(*b*) To bore 50 ft.—One each $3\frac{1}{4}$-in. and $2\frac{1}{4}$-in. clay augers, one each 3-in. and 2-in. shoe-nose shells, one $3\frac{3}{4}$-in. and two $2\frac{3}{4}$-in T-chisels, one each $3\frac{3}{4}$-in and $2\frac{3}{4}$-in. flat chisels, one pair rod-tillers, one auger-board, two 1-in lifting-dogs, two 1-in. hand-dogs, one bell-screw one spring-hook, 40 ft. of 3-in. rope, one auger-cleaner, four 10-ft. and one 5-ft by 1-in. boring-rods, one 5-ft. by 1-in. swivel-rod . 27*l.*

One set light tubular iron sheer-legs . 12*l.*

(*c*) To bore 100 ft.—One $2\frac{1}{4}$-in. clay auger, one each 3-in. and 2-in shoe-nose shells, two each $3\frac{1}{4}$-in. and $2\frac{1}{4}$-in. T-chisels, one each $3\frac{1}{4}$-in and $2\frac{1}{4}$-in. flat chisels, one pair rod-tillers, one auger-board, two 1-in. lifting-dogs, two 1-in hand-dogs, one crow's-foot, one bell-screw, one spring-hook, 40 ft $3\frac{1}{2}$-in. rope, one auger-cleaner, nine 10-ft. and one 5-ft. by 1-in. boring-rods, one 5-ft. by 1-in swivel-rod . . . . 38*l.*

One set light tubular iron sheer-legs . 12*l.*

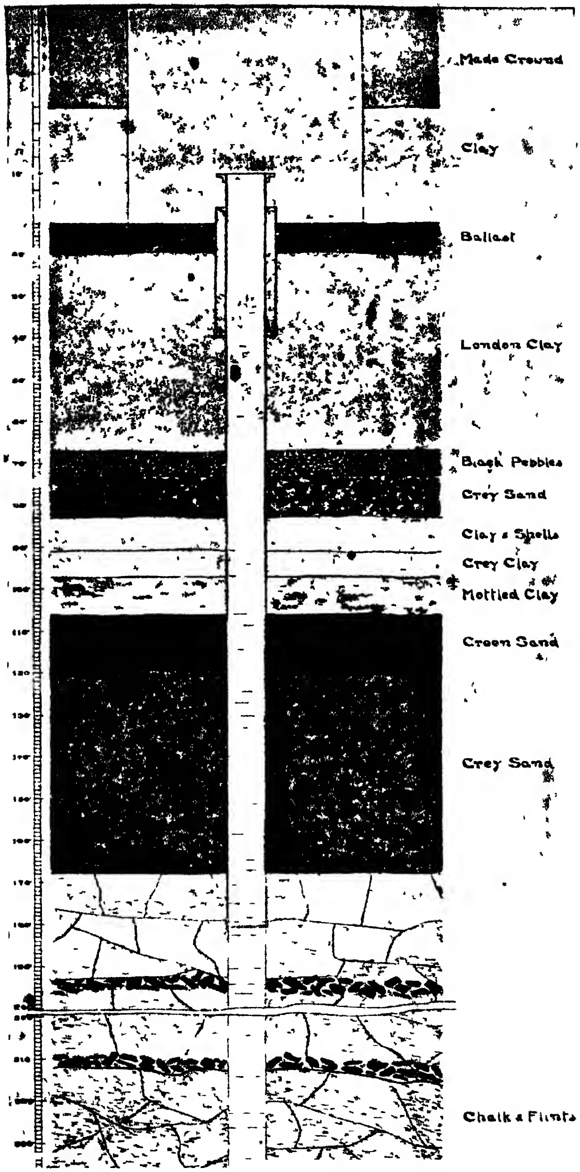


FIG 28G.—SECTION OF AN ARTESIAN BORED TUBE WELL AT CANNING TOWN. 400 ft. deep, 11⅜ in. internal diameter, minimum supply, 11,500 gals. per hour. Fixed by C Isler & Co.

(d) To bore 150 ft.—One each 4¼-in. and 3¼-in. clay augers, one each 4-in. and 3-in. shoe-nose shells fitted with latches for recovering broken tools, two each 4¾-in. and 3¾-in. T-chisels, one each 4¾-in. and 3¾-in. flat chisels, one pair rod-tillers and spare screws, one auger-board, two 1-in. lifting-dogs, two 1-in. hand-dogs, one crow's-foot, one spring-hook, 40 ft. of 4½-in. rope with rope slings and punching-rope, one auger-cleaner, fourteen 10-ft. and one 5-ft. by 1-in. boring-rods, one 5-ft. by 1-in. swivel-rod . . . . . 45*l.*

One set sheer-legs and gearing . . . . 18*l.*

Fitted with fast and loose pulleys. . 5*l*

(*e*) To bore 200 ft.—One each 5¼-in, 4¼-in and 3¼-in clay augers, one each 5-in, 4-in. and 3-in shoe-nose shells fitted with latches for recovering broken tools, two each 5¾-in., 4¾-in and 3¾-in. T-chisels, one each 5¾-in., 4¾-in. and 3¾-in. flat chisels, one pair rod-tillers and spare screws, one auger-board, two 1¼-in lifting-dogs, two 1¼-in. hand-dogs, one crow's-foot, one spring-hook, 40 ft of 4½-in. rope with rope-slings and punching-rope, one auger-cleaner, nineteen 10-ft and one 5-ft. by 1¼-in boring-rods, one 5-ft by 1¼-in swivel-rod . . . 68*l.*

One set sheer-legs and gearing . 23*l.*

Fitted with fast and loose pulleys 7*l.*

(*f*) To bore 300 ft.—One each 6¼-in., 5¼-in. and 4¼-in clay augers, one each 6-in, 5-in and 4-in. shoe-nose shells fitted with latches for recovering broken tools, two each 6¾-in., 5¾-in. and 4¾-in. T-chisels, one each 6¾-in., 5¾-in and 4¾-in. flat chisels, one pair rod-tillers with spare screws, one

auger-board, two $1\frac{1}{4}$-in. lifting-dogs, two $1\frac{1}{4}$-in. hand-dogs, one crow's-foot, one spring-hook, 40 ft. of $5\frac{1}{2}$-in. rope with rope-slings and punching-rope, one auger-cleaner, twenty-nine 10-ft. and one 5-ft. by $1\frac{1}{4}$-in boring-rods, one 5-ft. by $1\frac{1}{4}$-in. swivel-rod . . 90*l.*

One set sheer-legs and gearing 23*l.*

Fitted with fast and loose pulleys. 7*l.*

(*g*) To bore 400 ft.—One each $7\frac{1}{4}$-in., $6\frac{1}{4}$-in., $5\frac{1}{4}$-in. and $4\frac{1}{4}$-in. clay augers, one each 6-in., 5-in and 4-in. shoe-nose shells fitted with latches for recovering broken tools, two each $8\frac{1}{4}$-in., $6\frac{3}{4}$ in., $5\frac{3}{4}$-in. and $4\frac{3}{4}$-in. T-chisels, one each $8\frac{1}{4}$-in., $6\frac{3}{4}$-in., $5\frac{3}{4}$-in. and $4\frac{3}{4}$-in. flat chisels, one pair rod-tillers with spare screws, one auger-board, two each $1\frac{1}{2}$-in. and $1\frac{1}{4}$-in. lifting-dogs, two each $1\frac{1}{2}$-in and $1\frac{1}{4}$-in. hand-dogs, one crow's-foot, one spring-hook, 40 ft of $6\frac{1}{2}$-in. rope with rope-slings and punching-rope, one auger-cleaner, ten 10-ft. by $1\frac{1}{2}$-in. boring-rods, twenty-nine 10-ft. and one 5-ft by $1\frac{1}{4}$-in. boring-rods, one 5-ft. by $1\frac{1}{4}$-in. swivel-rod . 117*l.*

One set sheer-legs and gearing . . 30*l.*

Fitted with fast and loose pulleys 7*l* 10*s*

(*h*) To bore 500 ft.—One each $9\frac{1}{4}$-in., $7\frac{1}{4}$-in., $6\frac{1}{4}$-in. and $5\frac{1}{4}$-in clay augers, one each 7-in., 6-in. and 5-in. shoe-nose shells fitted with latches for recovering broken tools, two each $9\frac{1}{4}$-in., $8\frac{1}{4}$-in., $6\frac{3}{4}$-in. and $5\frac{3}{4}$-in T-chisels, one each $9\frac{1}{4}$-in., $8\frac{1}{4}$-in., $6\frac{3}{4}$-in and $5\frac{3}{4}$-in. flat chisels, one pair rod-tillers with spare screws, one auger-board, two each $1\frac{1}{2}$-in. and $1\frac{1}{4}$-in lifting-dogs, two each $1\frac{1}{2}$-in. and $1\frac{1}{4}$-in. hand-dogs, one spring-hook, 40 ft of $6\frac{1}{2}$-in rope with rope slings and punching-rope, one auger-cleaner,

twenty 10-ft. by 1½-in. boring-rods, twenty-nine 10-ft. and one 5-ft. by 1¼-in. boring-rods, one 5-ft. by 1¼-in swivel-rod . . . . . 150*l.*

One set sheer-legs and gearing . 35*l.*

Fitted with fast and loose pulleys. 10*l*

TUBES, AND APPLIANCES FOR FIXING THEM.

Internal diameter	3 in			4 in			5 in			6 in.			7½ in			8½ in		
Thickness	¼ ,,			¼ ,,			¼ ,,			5/16 ,,			5/16 ,,			5/16 ,,		
Price of—	£	*s*	*d*	£	*s*	*d*	£	*s*	*d*	£	*s*	*d*	£	*s*	*d*	£	*s.*	*d*
Tubes	0	4	0	0	5	0	0	6	0	0	9	0	0	11	0	0	15	0
Steel shoes	0	10	0	0	13	0	1	0	0	1	6	0	2	5	0	2	10	0
Pipe-clamps	1	5	0	1	7	6	1	10	0	2	0	0	2	10	0	3	10	0
Pipe-tillers	1	5	0	1	7	6	1	10	0	2	0	0	2	10	0	3	10	0
Driving-flanges	1	3	0	2	2	0	2	7	6	3	2	6	3	17	6	4	17	6
Pipe-hangers	0	10	0	0	13	0	0	18	0	1	0	0	1	5	0	1	17	6
Cast-iron flanges	0	3	0	0	6	0	0	10	0	0	12	0	0	18	0	1	4	0
Water-shells	1	2	0	1	10	0	1	10	0	2	0	0	2	0	0	2	15	0
Spring rimers	3	0	0	3	12	6	4	2	6	4	10	0	4	13	0	4	17	6
Spare blades for do	1	10	0	1	12	0	2	0	0	2	2	6	2	5	0	3	10	0
Circular chisels	3	10	0	4	12	6	5	10	0	6	7	6	7	14	0	10	0	0
Caps	0	5	0	0	7	0	0	9	0	0	11	0	0	17	0	1	0	0

Price of chain pipe-wrench from 1*l* 7*s*

Price of driving-monkeys. 300-lb, 3*l* 5*s*, 500-lb, 6*l*, 800-lb., 8*l* 10*s.*, 1600-lb, 17*l*

CHAPTER V.

KIND-CHAUDRON DEEP-BORING SYSTEM.

THE first really deep well was bored by Mulot, at Grenelle, for the City of Paris; it was commenced in 1832, and after more than eight years' incessant labour, water finally rose from the total depth of 1798 ft. Subsequently many wells have been sunk on the Continent, even deeper than the well of Grenelle, reaching in some cases to 2800 ft., but all of small diameter. German engineers introduced important modifications of the tools employed. Thus, Euyenhausen imparted a sliding movement to the striking part of the tool used for comminuting the rock, so that it always fell through a certain distance, producing a uniform action upon the rock at the bottom, and avoiding jar of the tools.

Kind, who had begun to apply his system to the sinking of large shafts for winning coal, was entrusted by the Municipal Council of Paris to bore a new well at Passy.

In sinking the Passy well, the weight of the trepan for comminuting the rock was about 36 cwt., the height through which it fell was nearly 2 ft., and its diameter was 39 in. The rods were of oak, about 8 in. on the side, and the dimensions of the cutting tool were limited to 39 in. because it worked the whole time in water; but generally the class of borings Kind undertook justified resorting to tools of great dimensions. When sinking shafts for winning coal, his operations required to be carried on with the full diameters of 10 to 14 ft., and he then drove a boring

40 in. diam. in the first instance, and subsequently enlarged this. There can be no objection to executing borings of this diameter ; but opposition to Kind's plan of sinking the Passy well was founded upon the assumption that he would not get a larger supply of water from the sub-Cretaceous formations than had been met with at Grenelle, where the diameter of the boring at bottom was not more than 8 in. It has been proved that there is a direct gain in adopting the larger borings, not only as regards the quantity of water to be derived from them, but also in their execution, arising from the fact that the tools can be made more secure against the effects of torsion or of concussion against the sides of the excavation, which is the cause of the most serious accidents met with in well-boring.

Kind's trepan embraces some peculiar details, which are shown in Fig 30. It is composed of two principal pieces—frame and arms, both of wrought iron, with the exception of the teeth of the cutting part, which are of cast steel The frame has at the bottom a series of slightly-conical holes, into which the teeth are inserted and tightly wedged The teeth are placed with their cutting edges on the longitudinal axis of the frame, and at the extremity of the frame are formed two heads, forged out of the same piece with the body of the tool, which also carries two teeth, placed in the same direction as the others, but of double their width, in order to render this part of the tool more powerful By increasing the dimensions of these end teeth, the diameter of the boring can be augmented, so as to compensate for the diminution of the clear space caused by the tube lining.

Above the lower part of the frame of the trepan, is a second piece, composed of two parts bolted together, and made to support the lower portion of the frame. This also

carries at its extremities two teeth, which serve to guide the tool in its descent, and to work off the projections left by the lower portion of the trepan. Above this, again, are the guides of the machinery, properly speaking, consisting of two pieces of wrought iron, arranged in the form of a cross, with the ends turned up, so as to preserve the machinery perfectly vertical in its movements, by pressing

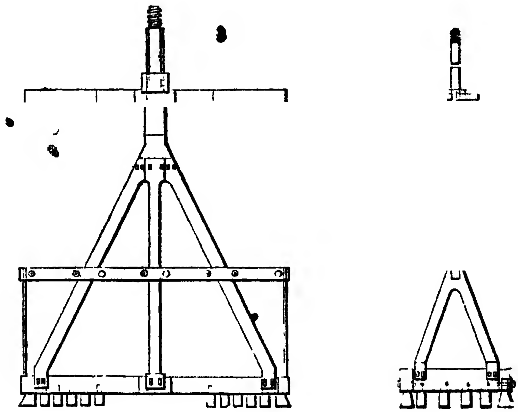


FIG. 30—KIND TREPAN.

against the sides of the boring already executed. These pieces are independent of the blades of the trepan, and may be moved closer to or farther from it, as desired. The stem and the arms are terminated by a single piece of wrought iron, which is joined to the frame with a kind of saddle-joint, and is kept in place by keys and wedges. The whole of the trepan is finally jointed to the great rods that communicate the motion from the surface, by means of a screw-coupling, formed below the part of the tool which bears the joint;

this arrangement permits the free fall of the cutting part, and unites the top of the arms and frame with the rod (Fig. 31). It has been proposed to substitute for this screw-coupling a keyed joint, in order to avoid the inconvenience frequently found to attend the rusting of the screw when it becomes necessary to withdraw the trepan.

FIG 31
KIND ROD.

The sliding joint was adopted by Kind from Euyenhausen's invention, and is one of the peculiarities of his system. So long as his operations were confined to the small dimensions usually adopted for well borings, he contented himself with making a description of joint with a "free-fall"--a simple movement of disengagement regulating the height fixed by the machinery itself, like the fall of the monkey in a pile-driving machine, but this did not answer when applied to large borings, and it presented certain dangers Kind, then, for the larger class of borings, availed himself of sliding guides, so contrived as to be equally thrown out of gear when the machinery had come to the end of the stroke, and maintained in their respective positions by being made in two pieces, of which the inner worked upon slides, moving freely in the piece that communicated the motion to the striking part of the machinery. The two parts of the tool were connected by pins, and with a sliding joint, which, in the Passy well, was thrown out of gear by the reaction of the column of water above the tool unloosing the click that upheld the lower part of the trepan, Fig 32. These departures from the usual way of releasing the tool and guiding it in its fall are condemned by some authorities, who object to the system of making the column of water act upon a disc to set the click in motion, as requiring

the presence of a column of water not always to be commanded, especially when boring in the Carboniferous strata

The rods used for suspension of the trepan, and for transmission of the blows to it, were of oak, this in itself constitutes a characteristic difference between the style of tools introduced by Kind and those made by the majority of well-borers. The resistance which wood offers by its elasticity to the effects of any sudden jar is also a point

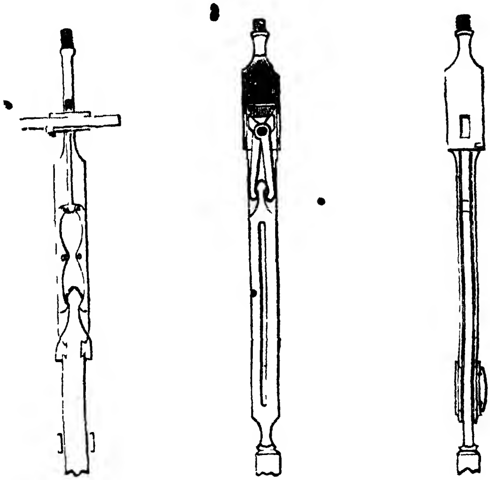


FIG 32.—SLIDING JOINTS

of superiority to iron, for the latter is liable to change its form under the influence of this cause. The resistance to torsion need not, however, be much dwelt on, for the turn given to the trepan is always made when the tool is lifted up from its bed Kind recommended that straight-grown trees of the requisite diameter should be selected, rather than that rods should be made of cut timber, as there is less danger of the wood warping, and the character of the wood is more homogeneous. He generally used these trees in

lengths of about 50 ft., and connected them at the ends with wrought-iron joints, fitting one into the other. The iron-*work of these joints is made with a shoulder underneath the screw-coupling,* to allow the rods to be suspended by the ordinary crow's-foot during the operation of raising or lowering. In the works executed at Passy, a frame was erected over the centre of the boring, of a height to allow of the rods being withdrawn in two lengths at a time, thus securing considerable economy of time and labour.

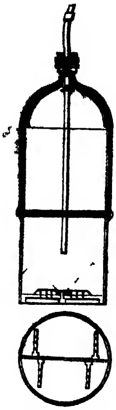


FIG. 33.—SHELL

As in other methods, Kind's system of removing the pounded rock involved withdrawal of the comminuting tool, in order that the "shell" might be inserted Kind's shell, Fig. 33, consisted of a cylinder of wrought-iron, suspended from the rods by a frame, and fastened to it at a little below the centre of gravity, so that the operation of upsetting it, when loaded, could be easily performed. This cylinder was lowered to the level of the last workings of the trepan, and the material already detached by that instrument was forced into the shell by the gradual movement of the latter in a vertical direction the bottom being made to open upwards, with hinged flaps. The ball-clack, Fig. 34, a most useful appliance for clearing holes, was not used by him.

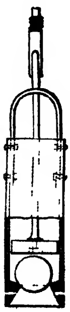


FIG 34.
BALL-CLACK.

At Passy great strength was given to the head of the striking tool, and to the part of the machinery applied to turn the trepan, because the great weight of the latter superinduced the danger of its break-

ing off under the influence of the shock, and because the solidity of this part of the machinery necessarily regulated *the whole working of the tool* *The head of the boring arrangement was connected with the* balance-beam of the steam-engine by a straight link-chain, with a screw-coupling, admitting of being lengthened as the trepan descended, Fig. 35. The balance-beam, in order to increase its elastic force in the upward stroke, is made of wood, in two pieces, the upper being of fir and the lower of beech. The whole of the machinery is put in motion by steam, which is admitted to the upper part of the cylinder, and presses it down, and thus raises the tool at the other end of the beam to that part in connection with the cylinder The counterpoise to the weight of the tools is also placed upon the cylinder-end of the beam. The cylinder receives the steam through ports that are opened and closed by hand, like those of a steam-hammer; so that the number and length of the strokes of the piston may be increased or diminished as occasion requires.

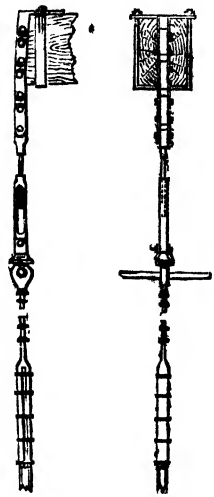


FIG 35 —COUPLING OF ROD TO ENGINE.

The balance-beam is continued beyond the point where the piston is connected with it, and goes to meet the blocks placed to check the force of the blow given by the descent of the tool. The guides of the piston-head are attached to the part of the machinery that acts in this manner; but at Passy, Kind made the balance-beam work upon two plummer-blocks having no permanent cover, that they might be more easily moved whenever it was necessary

to displace the beam, for the purpose of taking up or letting down the rods, or for changing the tools. The balance-beam was always immediately over the centre of the tools, and had to be displaced every time the latter required to be changed This was effected by allowing the beam to slide horizontally, so as to leave the mouth of the pit open. The counter-check, above mentioned, likewise prevented the piston from striking the cylinder-cover with too great force, when it was brought back by the weight of the tools to its original position The operation of raising and lowering the rods, or of changing the tools, was performed at Passy by a separate steam-engine, and the shell was discharged into a special truck, moving upon a railway expressly laid for this purpose in the great tower erected over the excavation

The cutting or comminution of the rock was usually effected at Passy at the rate of 15 to 20 strokes a minute. The rate of descent, of course, differed according to the nature of the rock operated upon ; but, generally speaking, the trepan was worked for the space of about 8 hours at a time, after which it was withdrawn, and the shell was let down in order to remove the debris The average number of men employed in the gang, besides the foreman or superintendent, was about 14. they comprised a smith and a hammerman, to keep the tools in order , and two shifts of men entrusted with the excavation, namely, an engine-driver and a stoker, a chief workman or sub-foreman, and 3 assistants The total time employed in sinking shafts upon this system in the north of France, where it was applied without meeting with the accidents encountered in the historical Passy well, could be divided in the following manner · 25 to 56% in manœuvring the trepan, 11 to 14½% in raising and lowering tools, 19 to 21% in removing material

detached from the rock and cleaning out the bottom of the excavation, and 8 to 10½% in stoppage of engines; broken tools, etc. In the Passy well the long delays caused by the slips which took place in the clays, both in the basement beds of the Paris basin and in the sub-Cretaceous strata,

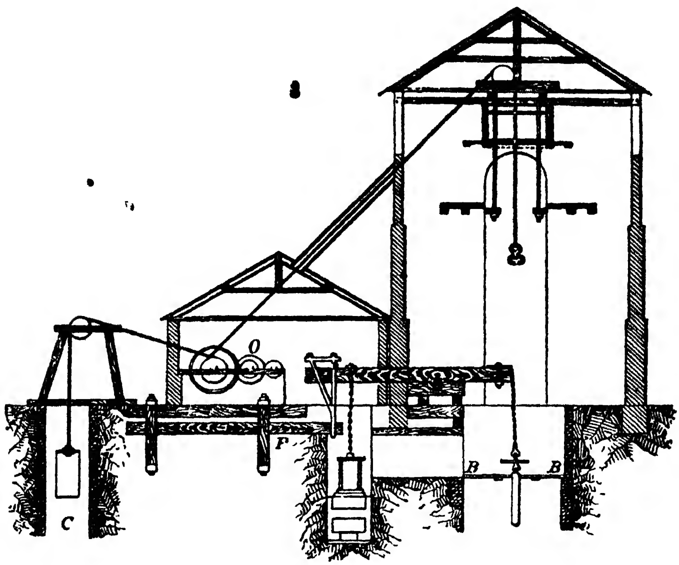


FIG. 36.—KIND-CHAUDRON PLANT

would render any comparison derived from it of little value.

Later, Chaudron made some modifications in Kind's practice, and the system became known by the dual name.

The arrangement of the surface plant is shown in Figs. 36 to 38. The small capstan engine O has a cylinder 20 in. diam. and a stroke of 32 in., working on the third motion. Attached to this engine, and working in the small pit C, is

a counter balance weight. The engine is used for raising and lowering boring-tools, and for lifting the debris resulting from the boring. As far as the platform, which is about 10 ft. from the surface, the pit is 19 ft. diam. or 4 ft. wider than below. At a level of about 38 ft. above this platform is a tramway on which run small trucks, carrying the "shell'

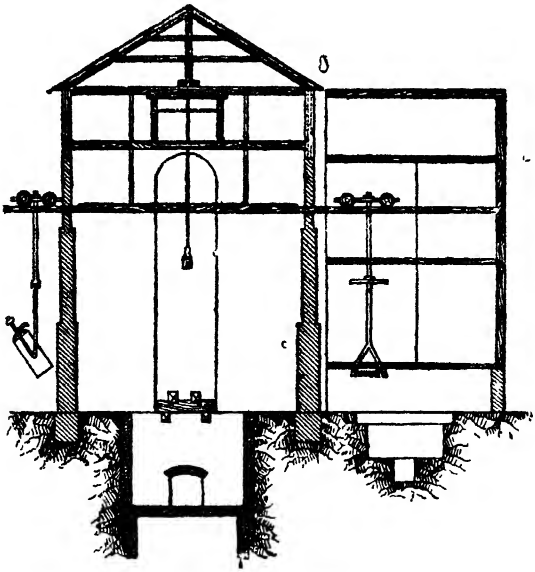


FIG. 37.—KIND-CHAUDRON PLANT.

on one side and the boring-tools on the other. At a level of 48 ft. above the platform are placed supports for the wooden spears to which the boring-tools are attached. The machinery for boring is worked by a cylinder, which has a diameter of $39\frac{1}{3}$ in. and a full stroke of $39\frac{1}{3}$ in., the usual stroke varying from 2 to 3 ft. A massive beam of wood transmits motion from this cylinder to the boring apparatus, the connection between the beam and the piston rod and

the beam and the boring-tools being made by a chain. The engine-man sits close to the engine, and applies the steam above the piston only. The down stroke of the boring-tools is caused by the sudden opening of the exhaust, and a frame then prevents the shock of the boring-rods from

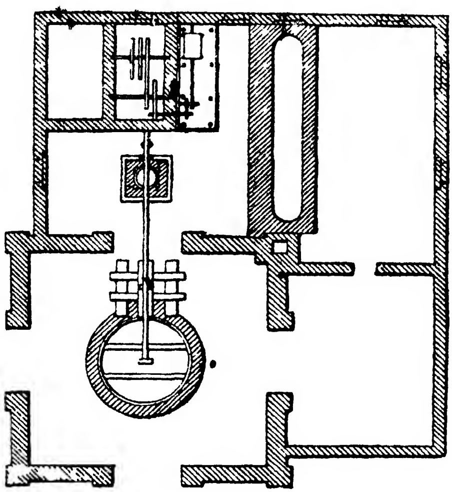


FIG. 38.—KIND-CHAUDRON PLANT.

being too severe. The engines work at speeds varying from 12 to 18 strokes a minute, according to the character of the strata passed through.

After the working platform is fixed, the first boring-tool applied is the small trepan, Fig 39. This tool is attached to the wooden beam by the arrangement already shown in Fig. 35. The boring-tools can be lowered at pleasure by means of an adjusting screw. The handle for boring is worked by 4 men on the platform, and is turned by the aid of a swivel. Attached to the handle-piece are rods made

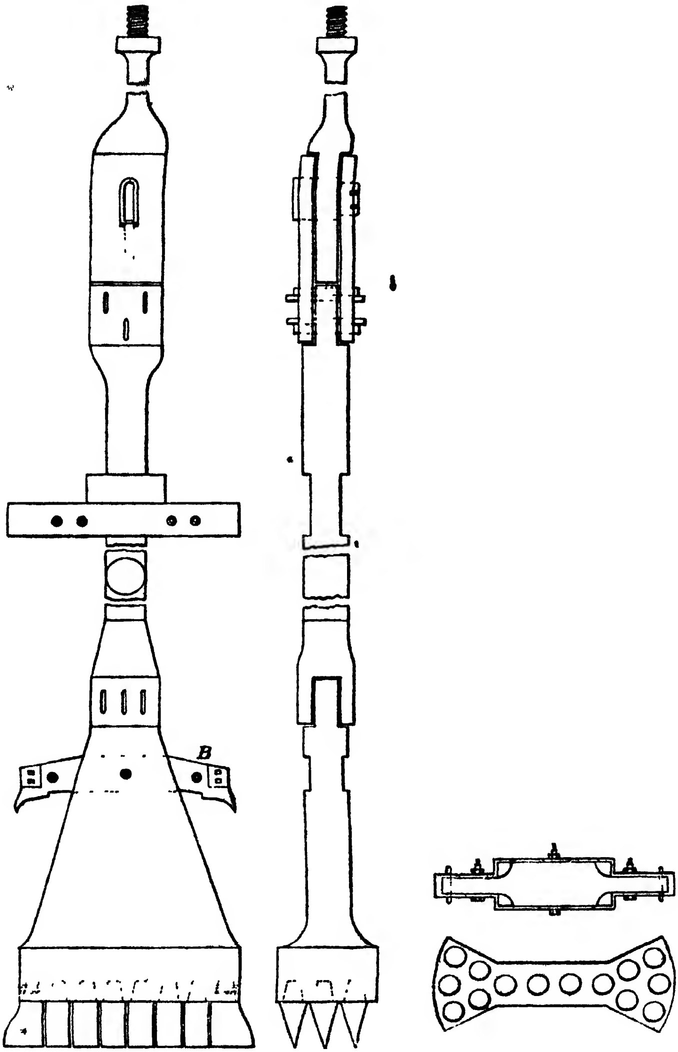


FIG. 39 —SMALL TREPAN.

from Riga pitch-pine, 59 ft. long and $7\frac{3}{4}$ in. square. A swivel-ring, Fig. 40 is attached to the rope when raising and lowering the boring-rods. The small trepan cuts a hole 4 ft. $8\frac{3}{4}$ in. diam., and has 14 teeth fitted in cylindrical holes

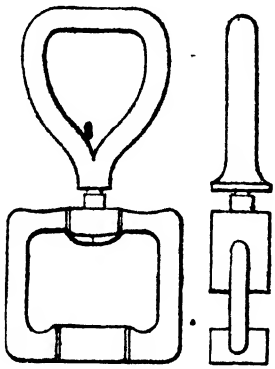


FIG. 40—SWIVEL-RING

and secured by pins entering through circular slots The teeth are steeled At a distance of 4 ft 4 in. above the main teeth of the trepan is an arm B, with a tooth at each end. This piece answers the purpose of a guide, and at the same time removes irregularities from the sides of the hole. At a distance of 13 ft 6 in. above the main teeth are the actual guides, consisting of two strong arms of iron fixed on the tool, and placed at right angles to each other. The hole made by the small trepan is not kept at any fixed distance in advance of the full-sized pit, but the distance generally varies from 30 to 100 ft. With the small trepan, which weighs 8 tons, progress varies from 6 to 10 ft a day.

The large trepan, Fig. 41, weighs $16\frac{1}{2}$ tons, is forged in one solid piece, and has 28 teeth. An iron projection forms the centre of this trepan, and fits loosely into the hole made by the small trepan, acting as a guide for the tool. At a

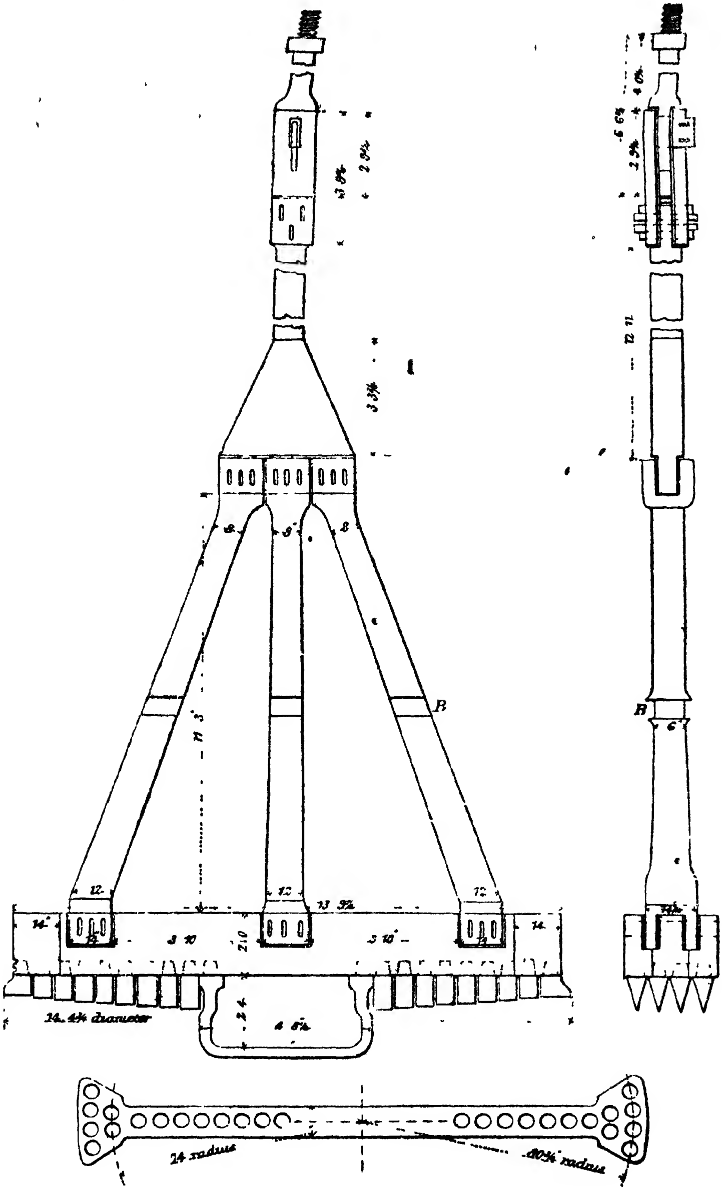


FIG. 41.—LARGE TREPAN.

distance of 7 ft. 6 in. above the teeth, a guide is sometimes fixed on the frame, but is not furnished with teeth. At a distance of 13 ft. 3 in. from the teeth are two other guides at right angles to each other. These guides are let down the pit with the boring-tool, the hinged part of the guides being raised whilst passing through the beams at the top of the pit, which are only 6 ft. 7 in apart. When the tool is ready to work, the two arms are let down against the side of the pit, and are hung in the shaft by ropes, thus

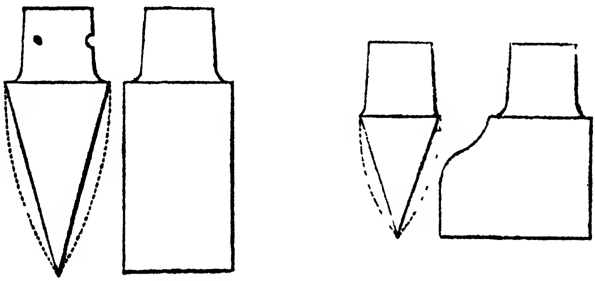


FIG. 42.—TREPAN TEETH.

acting as a guide for the trepan, which moves through them. To provide against a shock to the spears when the trepan strikes the rock on the down-stroke, at the upper part of the frame a slot motion is arranged, the play of which amounts to about ½ in. The teeth of the large trepan are not horizontal, but are deeper towards the inside of the pit, the face of the inside tooth being 3¾ in. lower than the outside. The object of this is to cause the debris to drop at once into the small hole, by the face of the rock at the bottom of the pit being somewhat inclined. The teeth used, Fig. 42, are the same both for large and small trepan, and weigh about 72 lb. each. As a rule, only one set of teeth is kept in use, this working for 12 hours, the alternate

12 hours being employed in raising the debris. This time is divided in about the following proportions:—Boring, 12 hours; drawing rods, 1 to 5 hours, according to depth; raising debris, 2 hours; lowering rods, 1 to 5 hours. The maximum speed of the larger trepan may be taken at about 3 ft. a day. The ordinary distance sunk is not more than 2 ft. a day, and in flint and other hard rocks the boring has proceeded as slowly as 3 in. a day.

The debris in the small bore-hole contains pieces of a maximum size of about 8 cub. in. In the large boring, pieces of rock measuring 32 cub. in. have been found. As a rule, however, the material is beaten very fine, having much the appearance of mud or sand. In both the large and the small borings the debris is raised by a shell, similar to Fig. 33, and consisting of a wrought-iron cylinder 39 in. diam. by 6 ft. 9 in. long, containing two flap-valves at the bottom, through which the excavated material enters. This apparatus is passed down the shaft by the bore-rods, and is moved up and down through a distance varying from 6 to 8 in. for about $\frac{1}{4}$ hour; it is then drawn up and emptied.

In some cases where the rock is hard, three sizes of trepan are used consecutively, the sizes being 5 ft., 8 ft. and 13 ft

Perpendicularity is ensured by the natural effect of the treble guide, which the chisels and the two sets of arms attached to the boring tools afford, and by the fact that if the least divergence is made from a vertical line the friction upon one side of the shaft is so great that the borers are unable to turn the instrument.

In tubbing, it is essential to secure a water-tight joint at the base; hence the bed on which the moss-box has to rest should be quite level and smooth. This is attained by the use of a "scraper" attached to the bore-rods.

The tubbing is cast in complete cylinders. At Maurage each ring has an internal diameter of 12 ft. and is 4 ft. 9 in high. Each ring has an inside flange at top and bottom, and a rib in the middle, the top and bottom of the ring being turned and faced. The rings of tubbing are attached to each other by 28 bolts 1·1 in. diam., passed through holes bored in the flanges. The tubbing is suspended in the pit by means of 6 rods, let down by capstans placed 30 ft. above the top of the pit and working upon long screws. When a new ring of tubbing is added, the rods are detached at a lower level, and are hung upon chains, thus leaving an open space for passing it forward. Before each ring is put into the pit it is tested to 50 per cent. more pressure than it is expected to be subjected to. The joints between the rings of tubbing are made with sheet lead $\frac{1}{8}$ in. thick coated with red-lead. The lead is allowed to obtrude from the joint $\frac{1}{3}$ in., and is wedged up by a tool which has a face $\frac{1}{12}$ in. thick.

The mode of suspending the tubbing from the rods will be understood by reference to Fig. 43. The rods are attached to a ring by the bolts connecting one ring of tubbing with another. The bottom ring of tubbing and the ring carrying the moss-box have their top flange turned inwards, but their bottom flange outwards. A strong iron web, forming the base of a tube 16½ in. diam., is attached to the tubbing. The object of this tube is to cause the water in the shaft to ease the suspension rods, by bearing part of the weight of the tubbing. Cocks to admit water are placed at intervals up the tube, by which means the weight upon the rods can be easily regulated, so that not more than 5 to 10 per cent. of the weight of the tubbing is suspended by the rods at one time. The ring holding the moss-box is hung from the bottom joint in the tubbing by sliding rods.

The arrangement of the moss-box, which forms the base of the tubbing is one of the most important points in this system of sinking. Ordinary peat moss is enclosed in a net, which, with the aid of springs, keeps it in place during the descent of the tubbing. When the moss-box, which

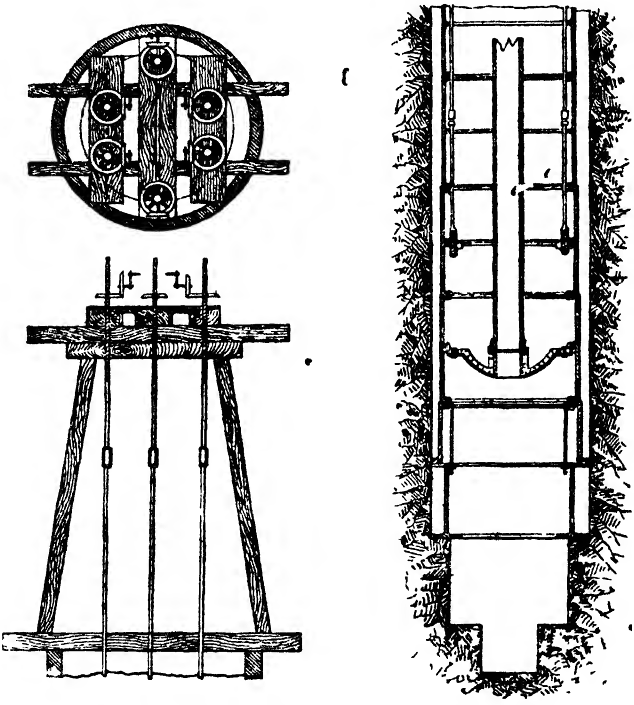


FIG. 43.—TUBBING SUSPENDED FROM RODS.

hangs on short rods fixed to the tubbing, reaches the face of rock, it is dropped gently upon it, and the whole weight of the tubbing is allowed to rest upon the bed : this compresses the moss, the capacity of the chamber holding it is

diminished, and the moss is forced against the sides of the hole, forming a water-tight joint.

Up to this point, the following important differences between this and the ordinary system of tubbing are to be observed. The tubbing, on reaching its bed, bears the aggregate pressure of all the feeders of water which have been met with ; no wedging or other mode of consolidating it in the shaft is used ; and connection between the rings is so carefully made that the wedging of joints is rendered unnecessary.

Finally, the annular space between the tubbing and the sides of the bore is filled with hydraulic cement, to render the tubbing impermeable.

CHAPTER VI.

DRU DEEP-BORING SYSTEM.

THE system applied by Dru is worthy of attention, not so much on account of its novelty or of any new principle involved, as on account of the contrivances it contains for the application of the free-falling tool to wells of large diameter. It has been already explained that under Kind's arrangement the trepan was thrown out of gear by the reaction of the water which was allowed to find its way into the column of the excavation, but that it is not always possible to command the necessary supply, and that, even when possible, the clutch Kind adopted was so shaped as to be subject to much and rapid wear.

Dru, with a view to obviate both these inconveniences, made his first trepan so that the tool was gradually raised until it came in contact with the fixed part of the upper machinery, when it was thrown out of gear. The bearings of the clutch were parallel to the horizontal line, and were found in practice to be more evenly worn, so that this instrument could be worked sometimes for 8 to 14 days without intermission, whereas, in Kind's system, the trepan was frequently withdrawn after 2 or 3 days' service.

It will be seen from Figs. 44, 45, that the boring-rod A is suspended from the outer end of the working beam B, which is made of timber hooped with iron, working upon a middle bearing, and is connected at the inner end to the vertical steam-cylinder C, 10 in. diam. and 39 in. stroke.

The stroke of the boring-rod is reduced to 22 in., by the inner end of the beam being made longer than the outer

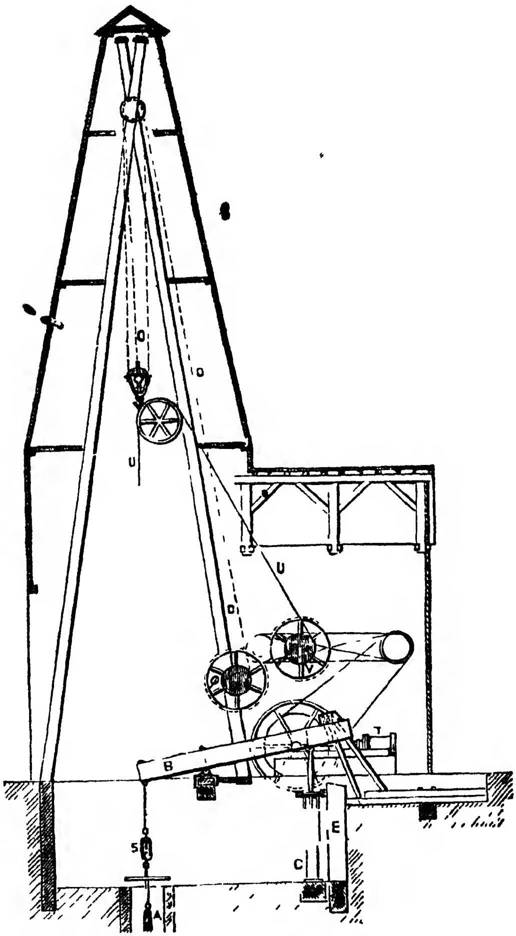


FIG. 44—DRU BORING PLANT

end, serving as a partial counterbalance for the weight of the boring-rod. The steam cylinder is single-acting, being

used only to lift the boring-rod at each stroke, and the rod is lowered again by releasing the steam from the top side of the piston; the stroke is limited by timber stops both below and above the end of the working beam B.

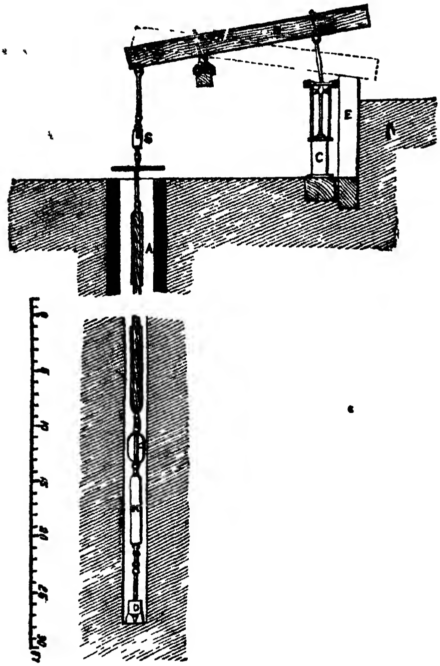


FIG. 45.—DRU BORING PLANT.

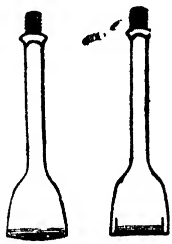


FIG. 46.—DRU CHISEL.

The boring-tool is the most important part of the apparatus, and has involved most difficulty in construction. The points to be aimed at in this are—simplicity of construction and repairs; greatest force of blow possible for each unit of striking surface; and freedom from liability to get turned aside and choked.

The tool used in small borings is a single chisel, as shown in Fig. 46; but for the large borings it is found best

to divide the tool-face into separate chisels, each of convenient size and weight for forging. All the chisels, however, are kept in a straight line, whereby the extent of striking surface is reduced, and the tool is rendered less liable to be turned aside by meeting a hard portion of flint on a single point of the striking edge, which would diminish the effect of the blow.

The trepan, Fig. 47, is composed of a wrought-iron body D, connected by a screwed end E to the boring-rod, and

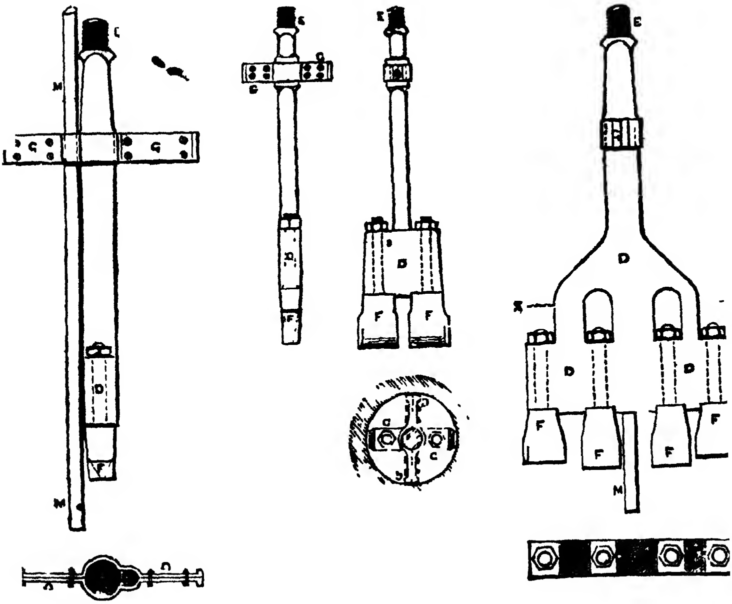


FIG. 47.—DRU TREPAN.

carrying the chisels F, fixed in separate sockets and secured by nuts above; 2 to 4 chisels are used, or sometimes even a greater number, according to the size of the hole to be bored. This construction allows of any broken chisel being

easily replaced; also, by changing the breadth of the two outer chisels, the diameter of the hole bored can be regulated exactly. When 4 chisels are used, the 2 centre ones are made a little longer than the others, to form a leading hole as a guide to the boring-rod. A cross-bar G, of the same width as the tool, guides it in the hole in a direction at right-angles to the tool; and in the case of the larger and longer tools, a second cross-bar higher up, at right-angles to the first and parallel to the striking edge of the tool, is also added.

If the whole length of the boring-rod were allowed to fall suddenly to the bottom of a large bore-hole at each stroke, frequent breakages would occur; it is therefore found requisite to arrange for the tool to be detached from the boring-rod at a fixed point in each stroke, and this has led to the general adoption of free-falling tools. Dru's plan of self-acting free-falling tool, liberated by reaction, is shown in side and front view in Fig 48. The hook H, attached to the head of the boring-tool D, slides vertically in the box K, which is screwed to the lower extremity of the boring-rod; and the hook engages with the catch J, centred in the sides of the box K, whereby the tool is lifted as the boring-rod rises. The tail of the catch J bears against an inclined plane L, at the top of the box K; and the two holes carrying the centre-pin I of the catch are made oval in vertical direction, so as to allow a slight vertical movement of the catch. When the boring-rod reaches the top of the stroke, it is stopped suddenly by the tail end of the beam B striking upon the wood buffer-block E (Fig. 44); the shock thus occasioned causes a slight jump of the catch J in the box K, the tail of the catch is thereby thrown outwards by the incline L, liberating the hook H, and the tool then falls freely to the bottom of the bore-hole. When the

boring-rod descends again after the tool, the catch J again engages with the hook H, enabling the tool to be raised for the next blow.

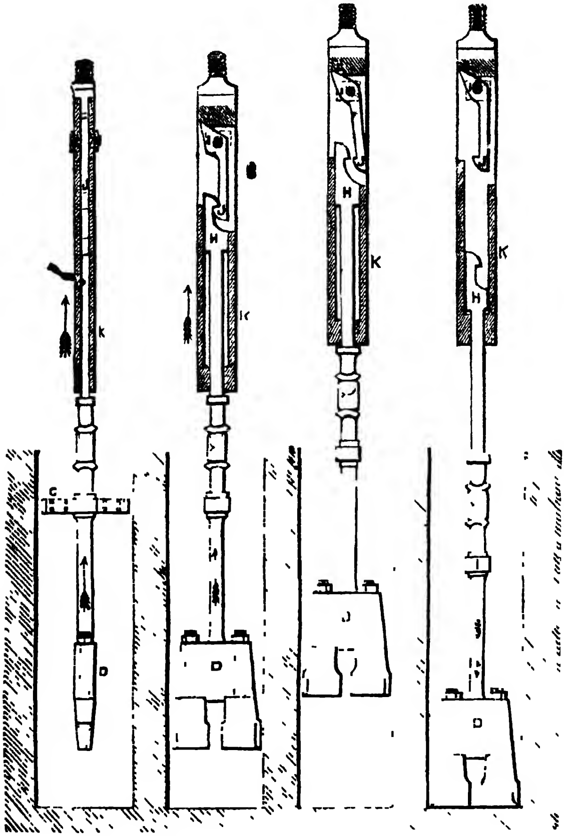


FIG 48.—DRU FREE-FALLING DEVICE

Another construction of the self-acting free-falling tool, liberated by a separate disengaging-rod, is shown in side and front view in Fig 49. It consists of 4 principal pieces—

the hook H, the catch J, the pawl I, and the disengaging-rod M. The hook H, carrying the boring-tool D, slides

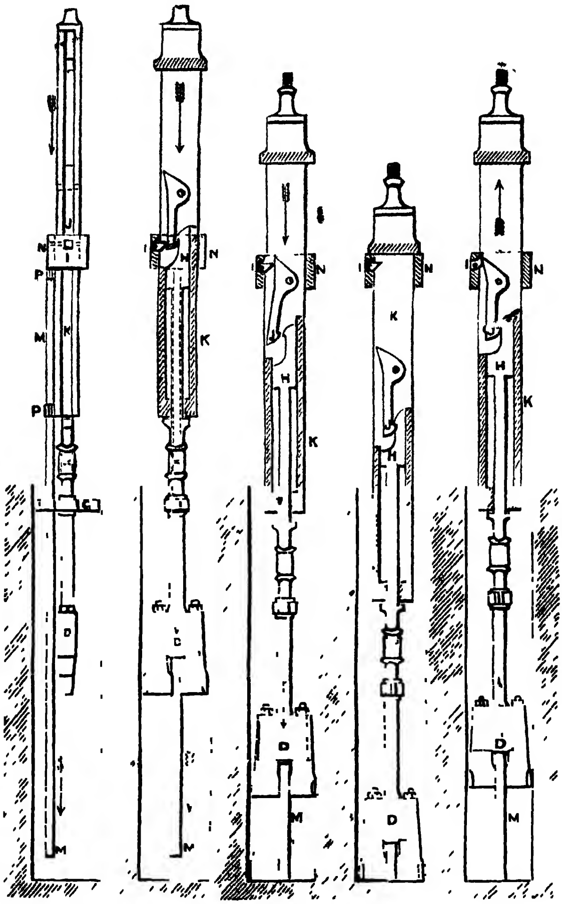


FIG 49.—FREE-FALLING DEVICE.

between the vertical sides of the box K, screwed to the bottom of the boring-rod, and the catch J works in the same space upon a centre-pin fixed in the box, so that

the tool is carried by the rod, when hooked on the catch. At the same time, the pawl I, at the back of the catch J, secures it from getting unhooked from the tool; but this pawl is centred in a separate sliding hoop N, forming the top of the disengaging-rod M, which slides freely up and down within a fixed distance upon the box K; and in its lowest position the hoop N rests upon the upper of the two guides P, through which the disengaging-rod M slides outside the box K. In lowering the boring-rod, the disengaging rod M reaches the bottom of the bore-hole first, and being then stopped, it prevents the pawl I from descending any lower; and the inclined back of the catch J sliding down past the pawl, the latter forces the catch out of the hook H, thus allowing the tool D to fall freely and strike its blow. The height of fall of the tool is always the same, being determined only by the length of the disengaging-rod M.

The blow having been struck, and the boring-rod continuing to be lowered to the bottom of the hole, the catch J falls back into its original position, and engages again with the hook H, ready for lifting the tool in the next stroke. As the boring-rod rises, the tail of the catch J trips up the pawl I in passing, allowing the catch to pass freely, and the pawl, before it begins to be lifted, returns to the original position, where it locks the catch J, and prevents any risk of its becoming unhooked either in raising or lowering the tool in the well.

The tool employed for boring a well 19 in. diam. weighs $\frac{3}{4}$ ton, and is liberated by the reaction arrangement shown in Fig 48. The same mode of liberation was applied in the first instance to the larger tool employed in sinking a well 47 in. diam.: the great weight of the latter tool, however, amounting to as much as $3\frac{1}{2}$ tons, necessitated so

violent a shock for the purpose of liberating the tool by reaction, that the boring-rods and the rest of the apparatus would have been damaged, and the arrangment shown in Fig. 49 was substituted. In this case, the cross guide G fixed upon the tool is made with an eye for the disengaging-rod M to work through freely. For borings of small diameter, however, the disengaging-rod cannot supersede the reaction system of liberation, as the latter alone is able to work in borings (as small as 3¼ in. diam.; and a bore-hole no larger than this has been successfully completed with the reaction tool to a depth of 750 ft.

The boring-rods employed are of wrought iron and of wood. Wooden rods are used for borings of large diameter, as they possess the advantage of having a larger section for stiffness without increasing the weight, also, when immersed in water, the greater portion of their weight is floated. The wood requires to be carefully selected, and from the thick part of the tree In France, Lorraine or Vosges deals are preferred.

The boring-rods, whether of wood or iron, are screwed together either by solid sockets or with separate collars. The latter are preferred, being easy to forge, also because, as only one half of the collar works in coupling and uncoupling the rods, while the other half is fixed, the screw thread becomes worn only at one end, and, by changing the collar end for end, a new thread is obtained when one is worn out, the worn end being then jammed fast as the fixed end of the collar

In raising or letting down the boring-rod, two sections of about 30 ft. each are detached or added at once, and a few shorter rods of different lengths are used to make up the exact requirement. The coupling-screw (S, Fig. 44), by which the boring-rod is connected to the working

beam B, serves to complete the adjustment of length; this is turned by a cross-bar, and then secured by a cross-pin through the screw.

In ordinary work, breakages of the boring-rod generally take place in the iron, and more particularly at the part screwed, that being the weakest. In case of breakages, the tools usually employed for picking up the broken ends are a conical screwed socket (Fig. 50) and a crow's-foot (Fig 51); the socket is made with an ordinary V-thread for cases where the breakage occurs in iron, but with a sharper thread like a wood screw when the breakage is in wood rods. To

FIG. 50.

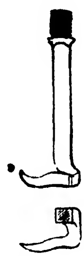


FIG 51

FIG 52

EMERGENCY TOOLS

ascertain the shape of the fractured end left in the bore-hole, and its position relatively to the centre line of the hole, a similar conical socket is first lowered, having its under surface filled up level with wax, so as to take an impression of the broken end, and show what size of screwed socket should be employed for getting it up. Tools with nippers are sometimes used in large borings, as it is not advisable to subject the rods to a twist.

When the boring-tool has detached a sufficient quantity of material, the boring-rod and tool are drawn up by means of the rope O (Fig. 44) winding up the drum Q, which is

driven by straps and gearing from the steam-engine T. A shell is then lowered into the bore-hole by the wire-rope U, from the other drum V, and is afterwards drawn up again with the excavated material. A friction brake is applied to the drum Q, for regulating the rate of lowering the boring-rod. The shell shown in Fig. 52 consists of a riveted iron cylinder, with a handle at the top, which can either be screwed to the boring-rod or attached to the wire-rope, and the bottom is closed by a large valve opening inwards. Two forms are used, either a pair of flap-valves, or a single-cone valve; and the bottom ring of the cylinder, forming the seating of the valve, is forged solid, and steeled on the lower edge. In lowering this cylinder to the bottom of the bore-hole, the valve opens, and the loose material enters the cylinder, where it is retained by the closing of the valve, whilst the shell is drawn up again to the surface In boring through chalk, as in the case of the deep wells in the Paris basin, the hole is first made of about half the final diameter for 60 to 90 ft, and is then enlarged to the full diameter by using a larger tool. This is done for convenience of working: if the whole area were acted upon at once, it would involve crushing all the flints in the chalk; but, by putting a shell in the advanced hole, the flints that are detached during the working of the second larger tool are received in the shell and removed by it, without getting broken by the tool.

The resistance experienced in boring through different strata is various, and some rocks passed through are so hard that with 12,000 blows a day of a boring-tool weighing nearly 10 cwt., with 19 in. height of fall, the bore-hole was advanced only 3 to 4 in. a day. As an opposite case, strata of running sand have been met with so wet that a slight movement of the rod at the bottom of the hole was sufficient

to make the sand rise 30 to 40 ft in the bore-hole. In these cases, Dru adopted the Chinese method of effecting a speedy clearance, by means of a shell closed by a large ball-clack at the bottom (Fig. 52), suspended by a rope, to which a vertical movement is given; each time the shell falls upon the sand, a portion of this is forced up into the cylinder, and retained there by the ball-valve

Dru states that the reaction tool has been successfully employed for borings up to about 4 ft diam, witness the case of the well at Butte-aux-Cailles of 47 in. diam.; but beyond that size he considers the shock requisite to liberate the larger and heavier tool would probably be so excessive as to injure the boring-rods and the rest of the attachments, and he designed the arrangement of the disengaging-rod for liberating the tool in borings of large diameter, whereby all shock upon the boring-rods is avoided, and the tool is liberated with complete certainty.

In practice it is necessary, as with the common chisel, to turn the boring-tool partly round after each stroke, so as to prevent it from falling every time into the same position at the bottom of the well, this was effected in the well at Butte-aux-Cailles by manual power at the top of the well, a long hand-lever fixed to the boring-rod by a clip bolted on being turned round by a couple of men through part of a revolution during the time that the tool was being lifted The turning was ordinarily done in the right-hand direction only, so as to avoid the risk of unscrewing any of the screwed couplings of the boring-rods, and care was taken to give the boring-rod half a turn when the tool was at the bottom, so as to tighten the screw-couplings, which otherwise might shake loose. In the event of a fracture, however, leaving a considerable length of boring-rod in the hole, it was sometimes necessary to have the means of unscrew-

ing the couplings of the portion left in the hole, so as to raise it in parts, instead of all at once. In that case, a locking-clip was added at each screwed joint above, and secured by bolts, at the time of putting the rods together for lowering them down the well to recover the broken portion ; and by this means the ends of the rods were prevented from becoming unscrewed in the coupling-sockets, when the rods were turned round backwards for unscrewing the joints in the broken length at the bottom of the bore-hole.

When running sands are met with, the plan adopted is to use the Chinese ball-scoop or shell, Fig. 52 , where there is too much sand for it to be got rid of in this way, a tube has to be sent down from the surface to shut off the sand. This, of course, necessitates diminishing the diameter of the hole in passing through the sand , but on reaching the solid rock below the running sand, an expanding tool is used for continuing the bore-hole below the tubing with the same diameter as above it, so as to allow the tubing to go down with the hole.

In case of meeting with a surface of very hard rock at a considerable inclination to the bore-hole, Dru employs a tool with cutters fixed in a circle all round the edge, instead of in a single diameter line; the length of the tool is also considerably increased, so that it is guided for a length of 20 ft. He uses this tool in all cases where from any cause the hole is found to be going crooked, and has even succeeded thereby in straightening a hole that had previously been bored crooked. The cutting action of this tool is all round its edge , therefore on meeting with an inclined hard surface, as there is nothing to cut on the lower side, the force of the blow is brought to bear on the upper side alone, until an entrance is effected into the hard rock in a true straight line with the upper part of the hole.

Although as regards diameter, depth, and flow of water in favourable localities, extraordinary results have been obtained with this system of boring by rods worked by steam power, yet, as Dru himself observes, in some instances, "owing to the difficulties attending the operation, the occurrence of delays from accidents is the rule, while the regular working of the machinery is the exception." A further disadvantage to be noticed is that owing to the time and labour involved in raising and lowering heavy rods in borings of 10 in. diam and upwards, there is a strong inducement to keep the boring tool at work for a much longer period than is actually necessary for breaking-up fresh material at each stroke. The fact is that after 100 to 200 blows have been given, the boring-tool merely falls into the accumulated debris and pounds this into dust, without touching the surface of the solid rock It may therefore be easily understood how much time is totally lost out of the periods of 5 to 8 hours during which, with the rod system, the tool is allowed to continue working.

CHAPTER VII.

MATHER & PLATT DEEP-BORING SYSTEM.

IN Mather & Platt's method of boring adopted in England, rope has been reverted to in place of the iron or wooden rods used on the Continent. A flexible rope admits of being handled with greater facility than iron rods, but lacks the advantage of their rigidity; in the Chinese method (p. 41) it admitted of withdrawing the chisel or bucket very rapidly, but gave no certainty to the operation of the chisel at the bottom of the hole. Rods, on the other hand, enable a very effective blow to be given, with a definite turning or screwing motion between the blows, according to the requirements of the strata; but the time and trouble of raising heavy rods from great depths on each occasion of changing from boring to clearing out the hole form a serious drawback, which makes the stoppages occupy really a longer time than the actual working of the machinery.

The method introduced by Mather & Platt, of Oldham, has been largely employed for deep boring, and seems to combine many of the advantages of other systems without their disadvantages. Its distinctive features, as illustrated in Figs. 53 to 57, are the mode of giving the percussive action to the boring-tool, and the construction of the tool itself and of the shell-pump for clearing out the hole. Instead of these implements being attached to rods, they are suspended by a flat hemp rope, about ½ in. thick and 4½ in. broad, such as is commonly used at collieries; and

the boring-tool and shell-pump are raised and lowered as quickly in the bore-hole as the bucket and cages in a colliery shaft.

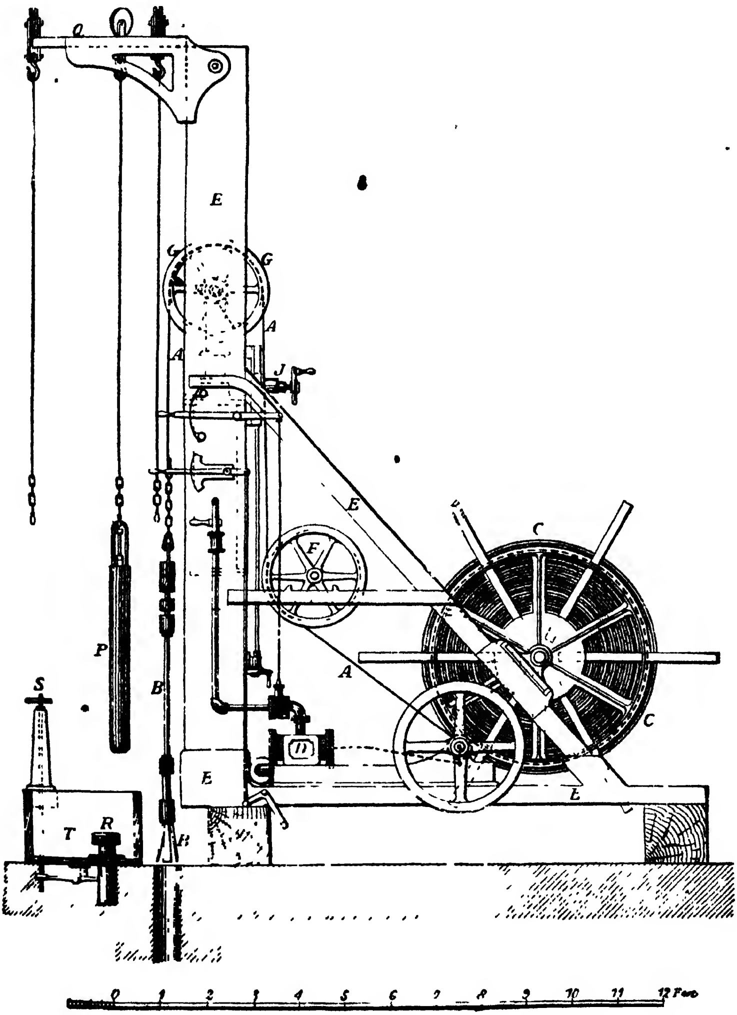


FIG. 53.—MATHER & PLATT BORING PLANT.

The flat rope A, Fig. 53, from which the boring-head B s suspended, is wound upon a large drum C driven by a

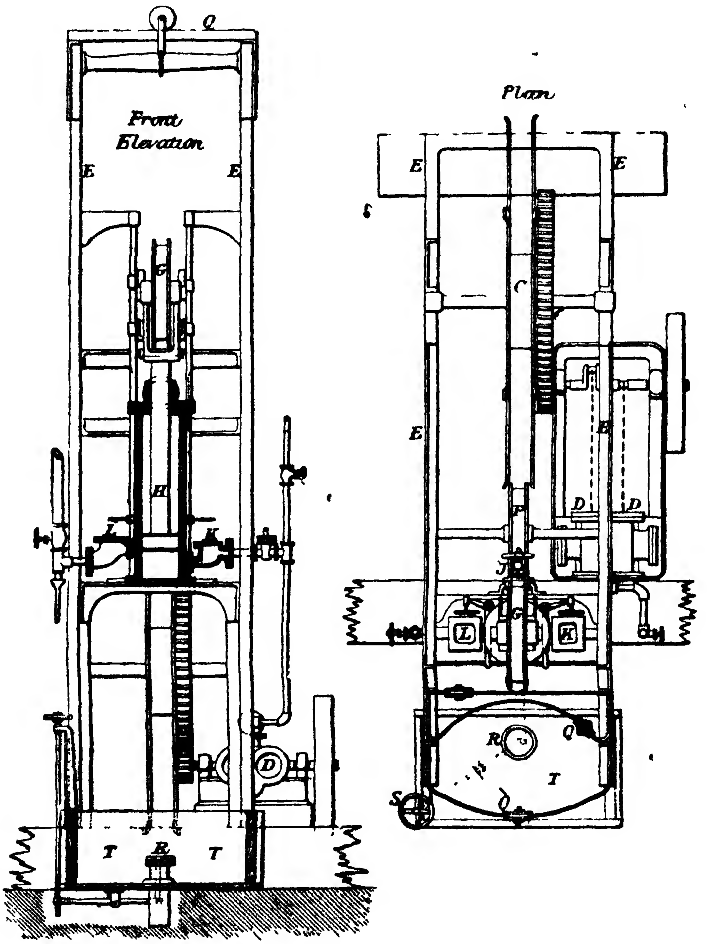


FIG. 54.—MATHER & PLATT SMALL BORING MACHINE.

steam-engine D with a reversing motion, so that one man can regulate the operation with the greatest ease. All the

working parts are fitted into a wooden or iron framing E, rendering the whole a compact and complete machine. On leaving the drum C, the rope passes under a guide-pulley F, and then over a large pulley G carried in a fork at the top of the piston-rod of a vertical single-acting steam-cylinder.

This cylinder, by which the percussive action of the boring-head is produced, is shown to a larger scale in the vertical sections, Figs. 55, 56, and in this larger machine the cylinder is fitted with a piston 15 in. diam. having a heavy cast-iron rod 7 in. square, which is made with a fork at the top, carrying the flanged pulley G of about 3 ft. diam and sufficient breadth for the flat rope A to pass over it. The boring-head having been lowered by the winding-drum to the bottom of the bore-hole, the rope is fixed secure at that length by the clamp J, steam is then admitted underneath the piston in the cylinder H by the steam-valve K, and the boring-tool is lifted by the ascent of the piston-rod and pulley G, on arriving at the top of the stroke, the exhaust-valve L is opened for the steam to escape, allowing the piston-rod and carrying-pulley to fall freely with the boring-tool, which descends with its full weight to the bottom of the bore-hole. The exhaust-port is 6 in. above the bottom of the cylinder, while the steam-port is situated at the bottom; there is thus always an elastic cushion of steam of that thickness retained in the cylinder for the piston to fall upon, preventing the piston from striking the bottom of the cylinder The steam- and exhaust-valves are worked with a self-acting motion by the tappets M, which are actuated by the movement of the piston-rod, and a rapid succession of blows is thus given by the boring-tool on the bottom of the bore-hole. As it is necessary that motion should be given to the piston before the valves can be acted upon, a small jet of steam N is allowed to be con-

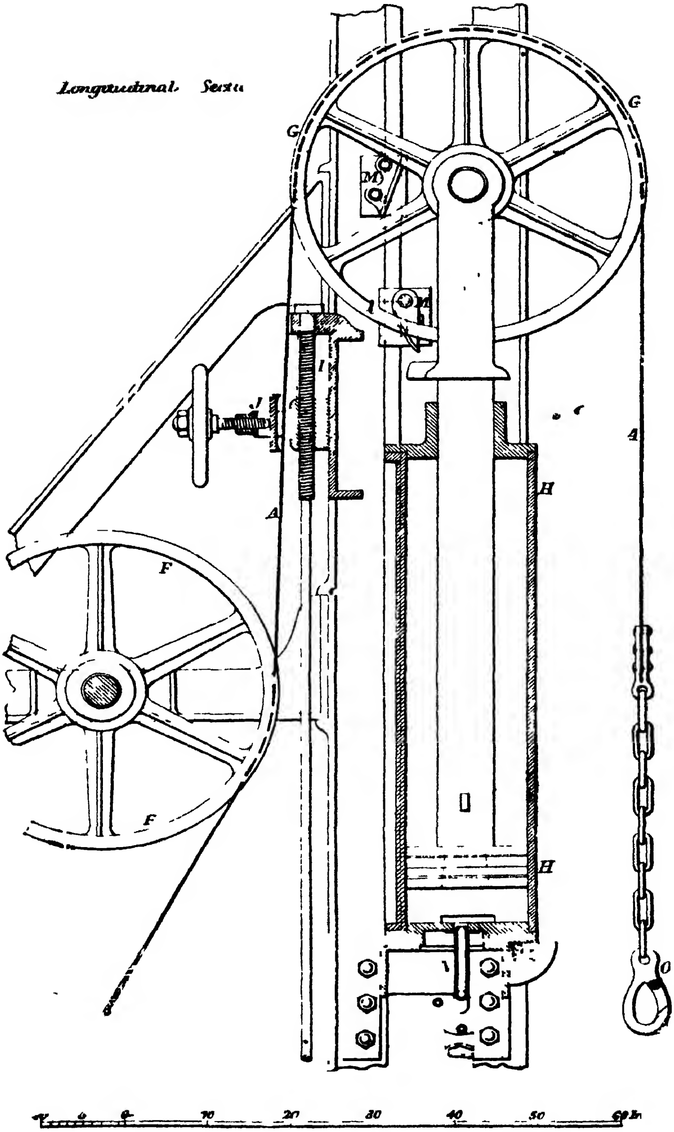


FIG. 55.—MATHER & PLATT LARGE BORING MACHINE.

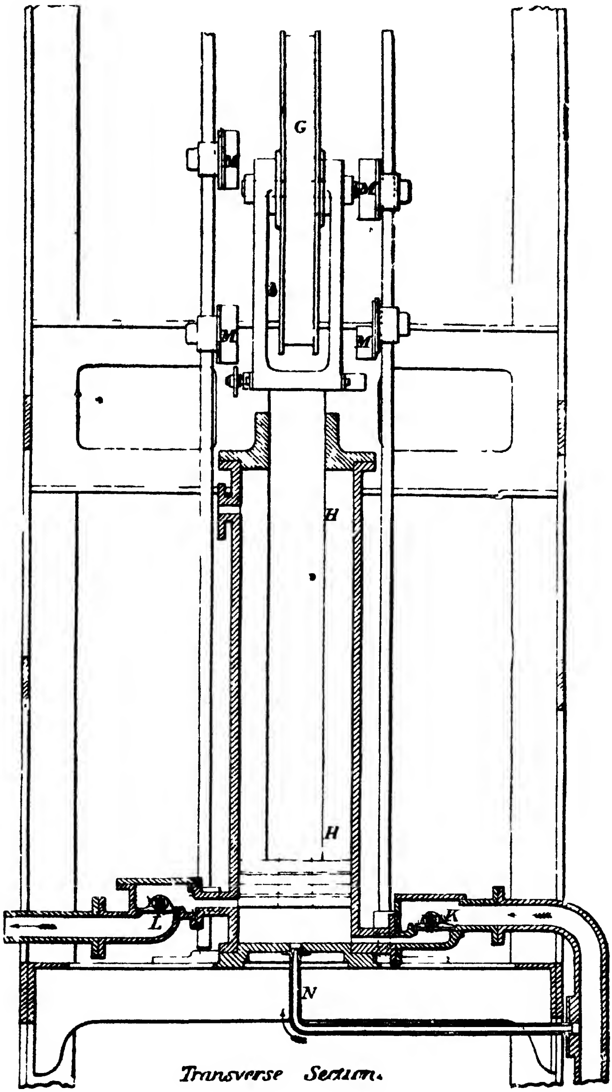


FIG. 56.—MATHER & PLATT LARGE BORING MACHINE.

stantly blowing into the bottom of the cylinder; this causes the piston to move slowly at first, so as to take up the slack of the rope, and allow it to receive the weight of the boring-head gradually and without a jerk. An arm attached to the piston-rod then comes in contact with a tappet which opens the steam-valve K, and the piston rises quickly to the top of the stroke; another tappet worked by the same arm then shuts off the steam, and the exhaust-valve L is opened by a corresponding arrangement on the opposite side of the piston-rod, as shown in Fig. 56 By shifting these tappets, the length of stroke of the piston can be varied from 1 ft. to 8 ft. in the large machine, according to the material to be bored through, and the height of fall of the boring-head at the bottom of the bore-hole is double the length of stroke of the piston. The fall of the boring-head and piston can also be regulated by a weighted valve on the exhaust-pipe, checking the escape of steam, so as to cause the descent to take place slowly or quickly, as may be desired.

The boring-head B, Fig 53, is shown to a larger scale in Fig. 57. It consists of a wrought-iron bar about 4 in. diam. and 8 ft long, to the bottom of which is secured a cast-iron cylindrical block C This block has numerous square holes through it, into which are inserted the chisels or cutters D, with taper shanks, so as to be very firm when working, but to be readily taken out for repairing and sharpening. Two different arrangements of the cutters are shown in the elevation and the plan. A little above the block C, another cylindrical casting E is fixed upon the bar B, and acts simply as a guide to keep the bar perpendicular. Higher still is fixed a second guide F, but on the circumference of this are secured cast-iron plates made with ribs of a saw-tooth or ratchet shape, catching only in one

direction; these ribs are placed at an inclination like segments of a screw-thread of very long pitch, so that, as the guide bears against the rough sides of the bore-hole when the bar is raised or lowered, they assist in turning it, and thus cause the cutters to strike in a fresh place at each stroke. Alternate plates have the projecting ribs inclined in opposite directions, so that one half of the ribs are acting to turn the bar round in rising, and the other half to turn it in the same direction in falling. These projecting spiral ribs simply assist in turning the bar, and immediately above the upper guide F is the arrangement by which the definite rotation is secured. To effect this object two cast-iron collars G H are cottered fast to the top of the bar B, and placed about 12 in. apart; the upper face of the lower collar G is formed with deep ratchet-teeth of about 2 in. pitch, and the under face of the top collar H is formed with similar ratchet-teeth, set exactly in line with those on the lower collar. Between these collars, and sliding freely on the neck of the boring-bar B, is a deep bush J, which is also formed with corresponding ratchet-teeth on both its upper and lower faces; but the teeth on the upper face are set half a tooth in advance of those on the lower face, so that the perpendicular side of each tooth on the upper face of the bush is directly above the centre of the inclined side of a tooth on the lower face. To this bush is attached the wrought-iron bow K, by which the whole boring-bar is suspended from a hook and shackle O, Fig. 55, at the end of the flat rope A.

The rotary motion of the bar is obtained as follows: When the boring-tool falls and strikes the blow, the lifting-bush J, which during the lifting has been engaged with the ratchet-teeth of the top collar H, falls upon those of the bottom collar G, and thereby receives a twist backwards

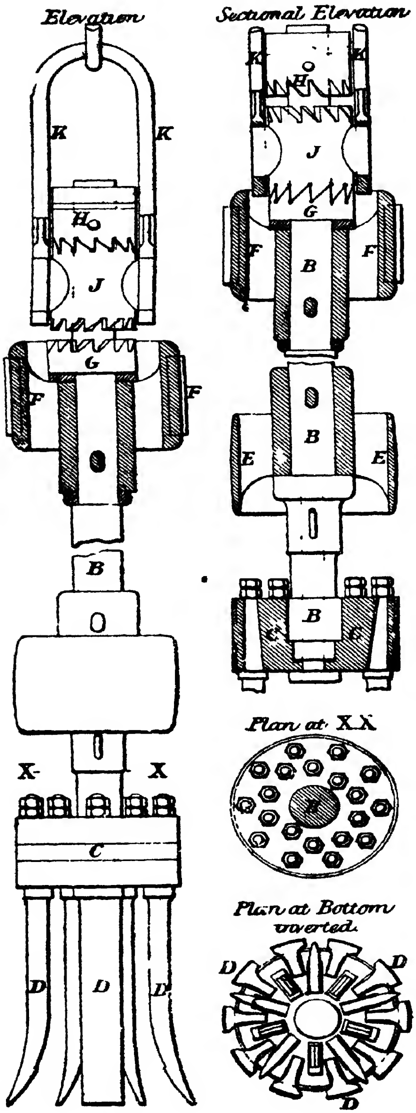


FIG. 57.—MATHER & PLATT BORING-HEAD.

through the space of half a tooth; and on commencing to lift again, the bush rising up against the ratchet-teeth of the top collar H, receives a further twist backwards through half a tooth. The flat rope is thus twisted backwards to the extent of one tooth of the ratchet; and during the lifting of the tool it untwists itself again, thereby rotating the boring-tool forwards through that extent of twist at each successive blow of the tool. The amount of the rotation may be varied by making the ratchet-teeth of coarser or finer pitch. The motion is entirely self-acting, and the rotary movement of the boring-tool is ensured with mechanical accuracy. This simple and most effective action, taking place at every blow of the tool, produces a constant change in the position of the cutters, thus increasing their effect in breaking the rock.

The shell-pump, for raising the material broken by the boring-head, is shown in Fig. 58, and consists of a cylindrical cast-iron shell or barrel P, about 8 ft long, and a little smaller in diameter than the size of the bore-hole. At the bottom is a clack A opening upwards, somewhat similar to that in ordinary pumps, but its seating, instead of being fastened to the cylinder P, is in an annular frame C, which is held up against the bottom of the cylinder by a rod D passing up to a wrought-iron guide E at the top, where it is secured by a cotter F. Inside the cylinder works a bucket B, similar to that of a common lift-pump, having a rubber disc-valve on the top side; and the rod D of the bottom clack passes freely through the bucket. The rod G of the bucket itself is formed like a long link in a chain, and by this link the pump is suspended from the shackle O at the end of the flat rope, the guide E, Fig. 58, preventing the bucket from being drawn out of the cylinder. The bottom clack A is made with a rubber disc, which opens

sufficiently to allow the water and smaller particles of stone to enter the cylinder ; and in order that pieces of broken

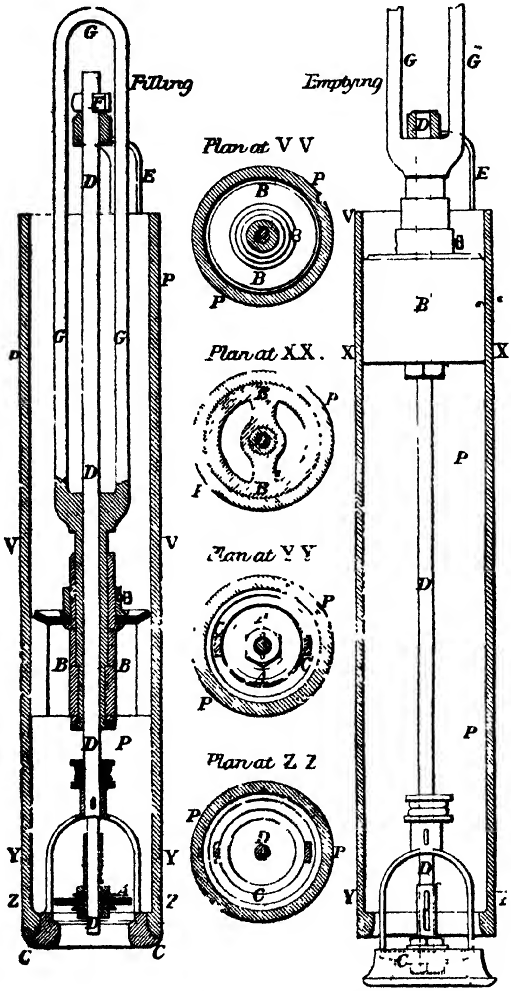


FIG 58 —MATHER & PLATT SHELL-PUMP.

rock may be brought up as large as possible, the entire clack is free to rise bodily about 6 in from the annular frame C, Fig. 58, thereby affording ample space for large pieces of rock to enter the cylinder, when drawn in by the up-stroke of the bucket

The general working of the boring-machine is as follows. The winding drum C, Fig 53, is 10 ft diam. in the large machine, and is capable of holding 3000 ft. of rope 4½ in. broad and 1½ thick When the boring-head B is hooked on the shackle at the end of the rope A, its weight pulls round the drum and winding-engine, and, by means of a brake, it is lowered steadily to the bottom of the bore-hole; the rope is then secured at that length by screwing up tight the clamp J. The small steam-jet N, Figs 55, 56, is next turned on, for starting the working of the percussion-cylinder H, and the boring-head is then kept continually at work, until it has broken up a sufficient quantity of material at the bottom of the bore-hole. The clamp J which grips the rope is made with a slide and screw I, Fig. 55, whereby more rope can be gradually given out as the boring-head penetrates deeper. In order to increase the lift of the boring-head and to compensate for the elastic stretching of the rope which is found to amount to 1 in. per 100 ft, it is simply necessary to raise the top pair of tappets on the tappet-rods whilst the percussive-motion is in operation. When the boring-head has been kept at work long enough, steam is shut off from the percussion-cylinder, the rope is unclamped, the winding-engine is put in motion, and the boring-head is wound up to the surface, where it is then slung from an overhead suspension-bar Q, Fig. 53, by means of a hook mounted on a roller for running the boring-head away to one side, clear of the bore-hole.

The shell-pump is next lowered into the bore-hole by the

rope, and the debris is pumped into it by lowering and raising the bucket about three times at the bottom of the hole; this is readily effected by means of the reversing-motion of the winding-engine. The pump is then brought to the surface and emptied by the following very simple arrangement: It is slung by a traversing-hook from the overhead suspension-bar Q, Fig. 53, and is brought perpendicularly over a small table R in the waste-tank T, the table being raised by the screw S until it receives the weight of the pump. The cotter F, Fig. 58, which holds up the clack-seating C at the bottom of the pump, is then knocked out, and the table being lowered by the screw, the whole clack-seating C descends with it, and the contents of the pump are washed out by the rush of water contained in the pump-cylinder. The table is then raised again by the screw, replacing the clack-seating in its proper position, where it is secured by driving the cotter F into the slot at the top; the pump is then ready to be lowered into the bore-hole as before. It is sometimes necessary for the pump to be emptied and lowered three or four times in order to remove all the material that has been broken up by the boring-head at one operation.

The rapidity with which these operations may be carried on is found by experience to be as follows The boring-head is lowered at the rate of 500 ft. a minute The percussive motion gives 24 blows a minute, this rate of working continued for about ten minutes in red sandstone and similar strata is sufficient for enabling the cutters to penetrate about 6 in., when the boring-head is wound up again at the rate of 300 ft. a minute. The shell-pump is lowered and raised at the same speeds, but only remains down about two minutes; and the emptying of the pump when drawn up occupies about two or three minutes.

In the construction of the machine it will be seen that the great desideratum of all earth-boring has been well kept in view; namely, to bore holes of large diameter to great depths with rapidity and safety. The main objects are to keep either the boring-head or the shell-pump constantly at work at the bottom of the bore-hole, where the actual work has to be done; to lose as little time as possible in raising, lowering, and changing the tools, to expedite all the operations at the surface, and to economise manual labour in every particular With this machine, one man standing on a platform at the side of the percussion-cylinder performs all the operations of raising and lowering by the winding-engine, changing the boring-head and shell-pump, regulating the percussive action, and clamping or unclamping the rope, all the handles for the various steam-valves are close to his hand, and the brake for lowering is worked by his foot. Two labourers attend to changing the cutters and clearing the pump. Duplicate boring-heads and pumps are slung to the overhead suspension-bar Q, Fig 53, ready for use, thus avoiding all delay when any change is requisite

In all well-boring innumerable accidents and stoppages are certain to occur from causes which cannot be prevented, with however much vigilance and skill the operations may be conducted. Hard and soft strata intermingled, highly inclined rocks, running sands, fissures and dislocations are fruitful sources of annoyance and delay, and sometimes of complete failure, and it will therefore be interesting to notice a few of the ordinary difficulties arising out of these conditions. The various special instruments used under such circumstances are shown in Figs. 59, 60.

The boring-head while at work may suddenly be jammed fast, either by breaking into a fissure, or in con-

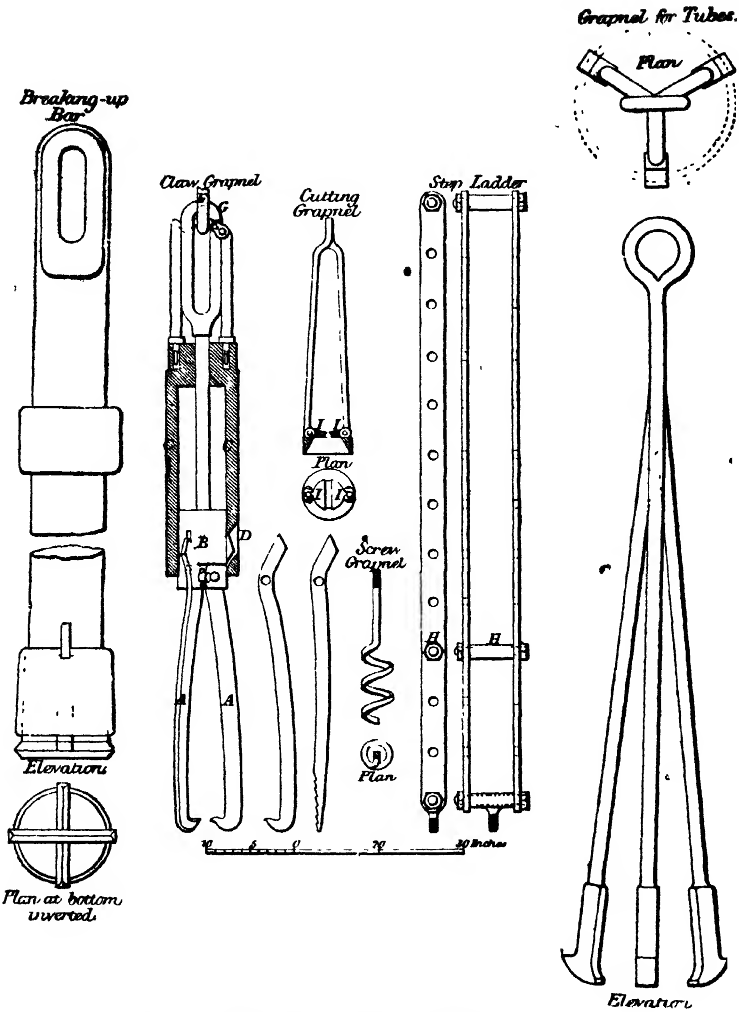


FIG. 59.—MATHER & PLATT EMERGENCY TOOLS.

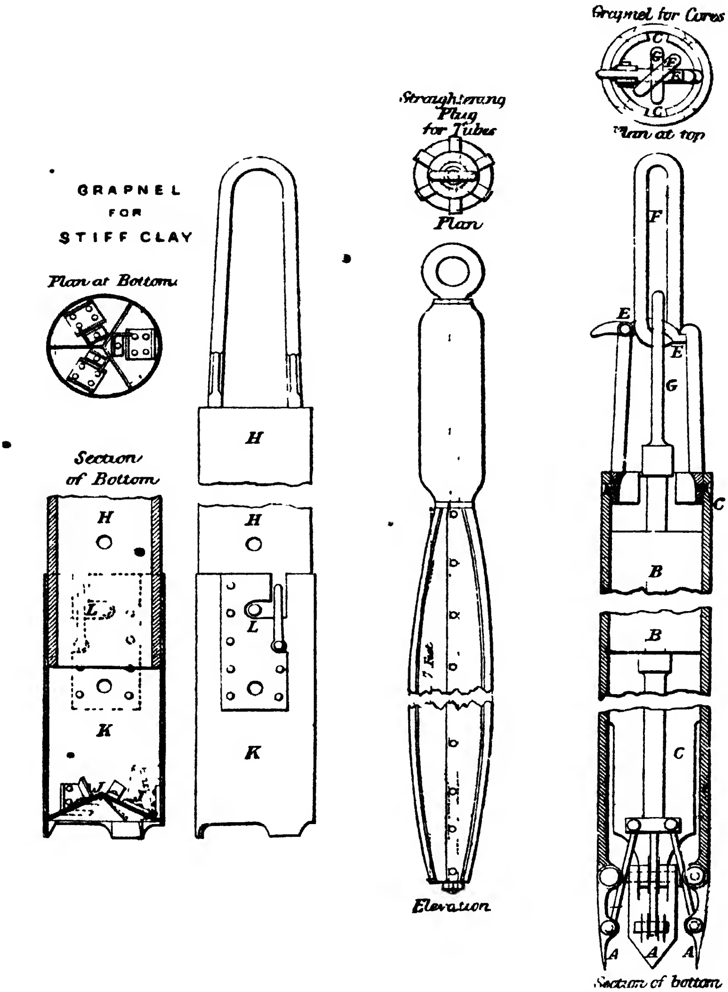


FIG. 60.—MATHER & PLATT EMERGENCY TOOLS.

sequence of broken rock falling upon it from loose strata above. All the strain possible is then put upon the rope, either by the percussion-cylinder or by the winding-engine: if the rope is old or rotten, it breaks, leaving perhaps a long length in the hole. The claw grapnel is then attached to the rope remaining on the winding-drum, and is lowered until it rests upon the slack broken rope in the bore-hole. The grapnel is made with three claws A centred in a cylindrical block B, which slides vertically within the casing C, the tail ends of the claws fitting into inclined slots D in the casing. During the lowering of the grapnel, the claws are kept open, in consequence of the trigger E being held up by the long link F, which suspends the grapnel from the top rope. But as soon as the grapnel rests upon the broken rope below, the suspending-link F continuing to descend allows the trigger E to fall out of it, and then, in hauling up again, the grapnel is lifted only by the bow G of the internal block B, and the entire weight of the external casing C bears upon the inclined tail ends of the claws A, causing them to close in tight upon the broken rope and lay hold of it securely. The claws are made either hooked at the extremity or serrated. The grapnel is then hauled up sufficiently to pull the broken rope tight, and wrought-iron rods 1 in square, with hooks attached at the bottom, are let down to catch the bow of the boring-head, which is readily accomplished. Powerful screw-jacks are applied to the rods at the surface, by means of the step-ladder shown in Fig. 59, in which the cross-pin H is inserted at any pair of the holes, so as to suit the height of the screw-jacks.

If the boring-head does not yield quickly to these efforts, the attempt to recover it is abandoned, and it is got out of the way by being broken into pieces. For this purpose, the broken rope in the bore-hole has first to be

removed ; it is therefore caught hold of with a sharp hook and pulled tight in the hole, while the cutting-grapnel is slipped over it and lowered by the rods to the bottom. This tool is made with a pair of sharp cutting jaws or knives I, opening upwards, which in lowering pass down freely over the rope ; but when the rods are pulled up with considerable force, the jaws nipping the rope between them cut it through, and it is thus removed altogether from the bore-hole.

The solid wrought-iron breaking-up bar, which weighs about a ton, is then lowered, and by means of the percussion-cylinder it is made to pound away at the boring-head until the latter is either driven out of the way into one side of the bore-hole, or broken up into such fragments as enable, partly by the shell-pump and partly by the grapnels, the whole obstacle to be removed The boring is then proceeded with, as before the accident.

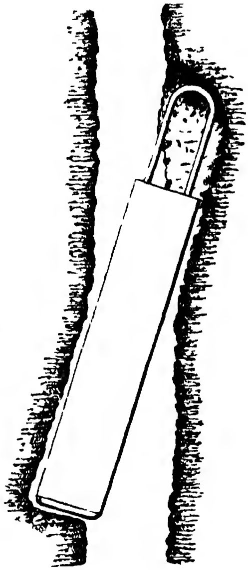


FIG. 61 —SHELL-PUMP FAST

The same mishap may arise from the shell-pump getting jammed fast in the bore-hole, as illustrated in Fig. 61 ; the same means of removing the obstacle are then adopted. Experience has shown the danger of putting any greater strain upon the rope than the percussion-cylinder can exert , it is therefore usual to lower the grapnel-rods at once, if the boring-head or pump gets fast, thus avoiding risk of breaking the rope

The breaking of a cutter in the boring-head is not an uncommon occurrence. If, however, the bucket-grapnel K

or the small screw-grapnel be employed for its recovery, the hole is usually cleared without any important delay. The screw-grapnel is applied by means of the iron grappling-rods, so that by turning the rods the screw works itself round the cutter or other article in the bore-hole, and securely holds it while the rods are drawn to the surface The bucket-grapnel, Fig. 60, is also employed for raising clay, as well as for the purpose of bringing up cores out of the bore-hole, where these are not raised by the boring-head itself in the manner already described. The action of this grapnel is similar to that of the claw-grapnel, Fig. 59. Where clay or similar material is at the bottom of the bore-hole, the weight of the heavy block B in the grapnel causes the sharp edges of the pointed jaws to penetrate to some depth into the material, a quantity of which is thus enclosed within them and brought up

Another grapnel also used where a bore-hole passes through a bed of very stiff clay is shown in Fig. 60, and consists of a long cast-iron cylinder, H, fitted with a sheet-iron mouthpiece K at the bottom, in which are hinged three conical steel jaws, J, opening upwards. The weight of the tool forces it down into the clay with the jaws open; on raising it, the jaws, having a tendency to fall, cut into the clay and enclose a quantity of it inside the mouthpiece, which, on being brought to the surface, is detached from the cylinder H and cleaned out A second mouthpiece is put on, and sent down for working in the bore-hole while the first is being emptied, the attachment of the mouthpiece to the cylinder being made by a common bayonet-joint L so as to admit of ready connection and disconnection.

Running sand in soft clay is the most serious difficulty met with in well-boring. Under such circumstances, the bore-hole has to be tubed from top to bottom, which greatly

increases the expense of the undertaking, not only by the cost of the tubes, but also by the time and labour expended on inserting them. When a permanent water supply is the main object of the boring, the additional expense of tubing the bore-hole is not of much consequence, it is, in fact, of distinct advantage, and should in all cases be provided for, as the tubed hole is more durable, and the surface water is thereby excluded, but in exploring for mineral, it is a serious matter, as the final result of the bore-hole is then by no means certain. The mode of inserting tubes has become a question of great importance in connection with this system of boring, and much time and thought having been spent in perfecting the method now adopted, its value has been proved by the repeated success with which it has been carried out

The tubes used by Mather & Platt are of cast iron varying in thickness from $\frac{5}{8}$ to 1 in., according to their diameter, and 9 ft. in length. Successive lengths are connected by means of wrought-iron covering-hoops 9 in. long, made of the same outside diameter as the tube, so as to be flush with it These hoops are $\frac{1}{4}$ to $\frac{3}{8}$ in thick, and the ends of each tube are reduced in diameter by turning down for $4\frac{1}{2}$ in. from the end, to fit inside the hoops A hoop is shrunk fast on one end of each tube, leaving $4\frac{1}{2}$ in. of socket projecting to receive the end of the next tube to be connected, four or six rows of screws with countersunk heads, placed at equal distances round the hoop, are screwed through into the tubes to couple the two lengths securely together. Thus a flush joint is obtained both inside and outside The lowest tube is provided at bottom with a steel shoe, having a sharp edge for penetrating the ground more readily The whole arrangement is, however, most cumbersome and unreliable, and compares very unfavourably with Isler's system described on a subsequent page.

In small borings 6 to 12 in. diam., the tubes are inserted by means of screw-jacks, as shown in Fig. 62. The boring-machine foundation A, which is of timber, is weighted at B

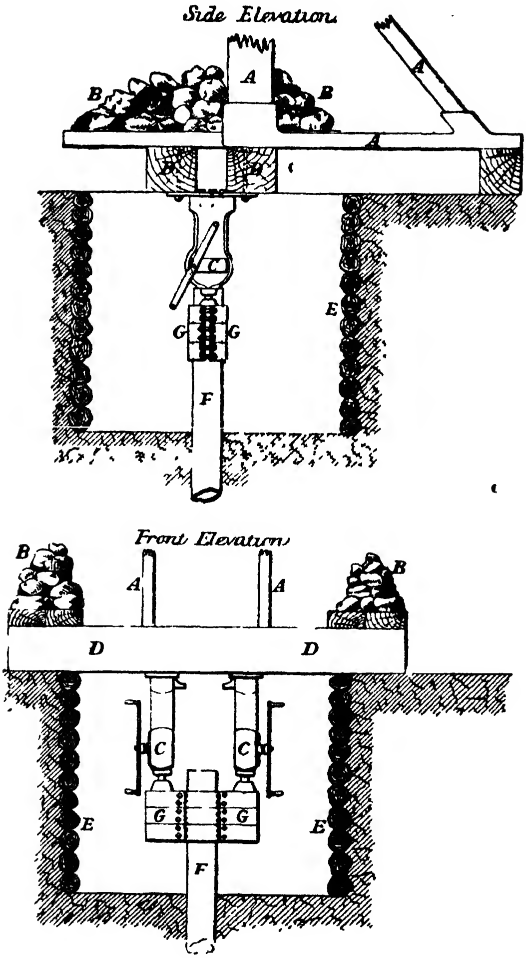


FIG. 62.—TUBE-FORCING BY SCREW-JACKS.

by stones, pig-iron, or any available material, and two screw-jacks C, each of about 10 tons power, are secured with the screws downwards, underneath the beams D crossing the shallow well E excavated at the top of the bore-hole. A tube F having been lowered into the mouth of the bore-hole by the winding-engine, a pair of deep clamps G are screwed tightly round it, and the screw-jacks acting upon these clamps force the tube down into the ground. The boring is then resumed, and as it proceeds the jacks are occasionally worked, so as to force the tube if possible even ahead of the boring-tool. The clamps are slackened and shifted up the tubes, to suit the length of the screws of the jacks; 2 men work the jacks, and couple the lengths of tubes as they are successively added. The actual boring is carried on simultaneously within the tubes, and is not in the least impeded by their insertion.

A more powerful apparatus is adopted where tubes of 18 to 24 in diam. have to be inserted to a great depth, an example of which is afforded by the boring at Horse Fort, Gosport. To supply the garrison with fresh water, a bore-hole is sunk into the chalk A cast-iron well, consisting of cylinders 6 ft. diam. and 5 ft. long, has been sunk 90 ft, and from the bottom of this well is an 18-in. bore-hole lined with cast-iron tubes 1 in. thick, coupled as before described. The method of inserting these tubes is shown in Fig. 63: two wrought-iron columns C, 6 in. diam, are firmly secured in the position shown, by castings bolted to the flanges of the cylinders A forming the well, so that the columns are perfectly rigid and parallel to each other. A casting D, carrying on its under-side two 5-in. hydraulic rams I, 4 ft. long, is formed so as to slide freely between the columns, which act as guides; the hole in the centre of this casting is large enough to admit freely a bore-tube, and by means

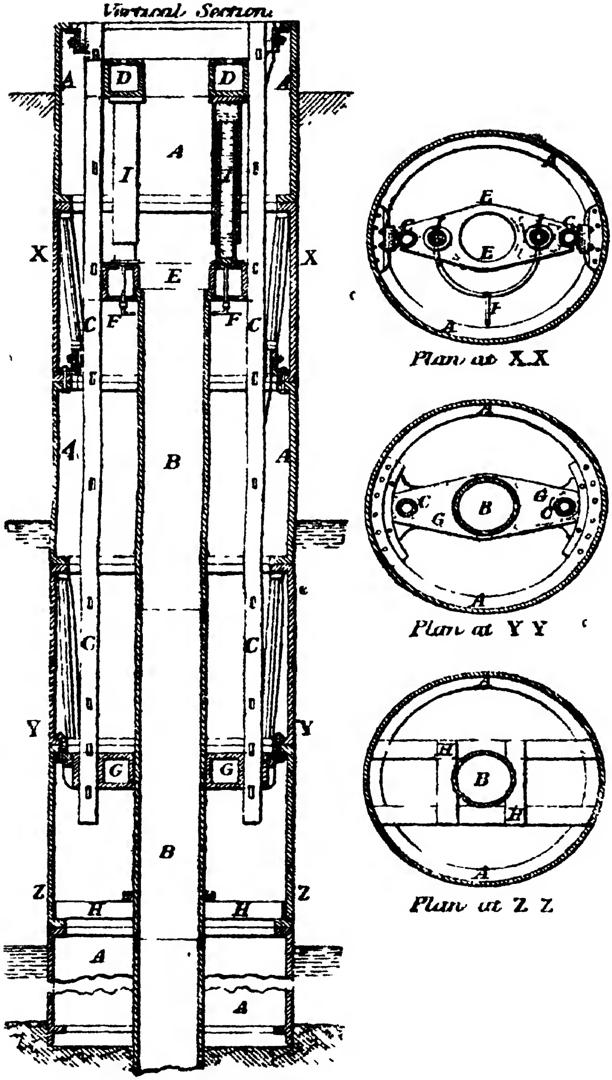


FIG 63.—TUBE-FORCING BY HYDRAULIC PRESS.

of cotters passed through the slots in the columns the casting is securely fixed at any height. A second casting E, exactly the same shape as the top one, is placed upon the top of the tubes B to be forced down, a loose wrought-iron hoop being first put upon the shoulder at the top of the tube, large enough to prevent the casting E from sliding down the outside of the tubes, this casting or crosshead rests unsecured on the top of the tube and is free to move with it. The hydraulic cylinders I, with their rams pushed home, are lowered upon the crosshead E, and the top casting D to which they are attached is then secured firmly to the columns C by cottering through the slots. A small pipe F, having a long telescope-joint, connects the cylinders I with the pumps at surface which supply the hydraulic pressure.

By this arrangement, a force of 3 tons per sq. in., or about 120 tons total upon the two rams, has frequently been exerted to force down the tubes at the Horse Fort. After the rams have made their full stroke of about 3 ft. 6 in., the pressure is let off, and the hydraulic cylinders I, with the top casting D, slide down the rams, resting on the crosshead E until the rams are again pushed home. The top casting D is then fixed in its new position upon the columns C, by cottering fast as before, and the hydraulic pressure is again applied; and this is repeated until the length of two tubes, making 18 ft., has been forced down. The whole hydraulic apparatus is then drawn up again to the top, another 18 ft. of tubing is added, and the operation of forcing down is resumed. The tubes are steadied by guides at G and H.

The boring operations are carried on uninterruptedly during the process of tubing, excepting only for a few minutes when fresh tubes are being added. It will be seen that the cast-iron well is in this case the ultimate abutment

against which the pressure is exerted in forcing the tubes down, instead of the weight of the boring-machine with stones and pig-iron added, as in the case where screw-jacks are used.

In the event of any accident occurring to the tubes while they are being forced down the bore-hole, such as requires them to be drawn up again, the core- or prong-grapnel, Fig. 60, is employed for the purpose; having three expanding hooked prongs, which slide readily down inside the tube, and spring open on reaching the bottom, the hooks project underneath the edge of the tube, which is thus raised on hauling up the grapnel. In case the tubes become crooked or indented, the long straightening-plug, Fig. 60, consisting of a stout piece of timber faced with wrought-iron strips, is lowered inside them; above this is a heavy cast-iron block, the weight of which forces the plug past the irregularity and thereby straightens them again.

CHAPTER VIII.

AMERICAN ROPE-BORING SYSTEM.

THE method of boring with a rope has received great development in the petroleum industry of the United States.

The derrick or sheer-frame employed is a tall framework of timber, 10 to 16 ft square at bottom and 30 to 80 ft. high. On the top is a strong framework for the reception of a pulley over which the drill-rope passes. The floor of the derrick is made firm by cross sleepers or "mud-sills" covered with planks. A roof for the protection of the workmen is arranged at 10 to 12 ft above the floor, and in cold weather the sides are boarded up. On one side of the derrick is arranged a windlass of peculiar construction called the "bull-wheel," and on the other is a steam-engine giving motion both to a connecting-rod which rocks the lever or working-beam, and (by means of a belt) to the bull-wheel The arrangement very much resembles that of the boring sheer-frame shown in Fig. 23 (p. 55), if the windlass were detached, and the lever were arranged to be worked by power.

A form of rig which is readily put up and taken down, and is adapted for transportation from place to place, is shown in Figs. 64 to 69, the illustrations being respectively a side elevation, a front elevation and a ground plan of the rig as a whole, a plan of the friction-wheels and brake-

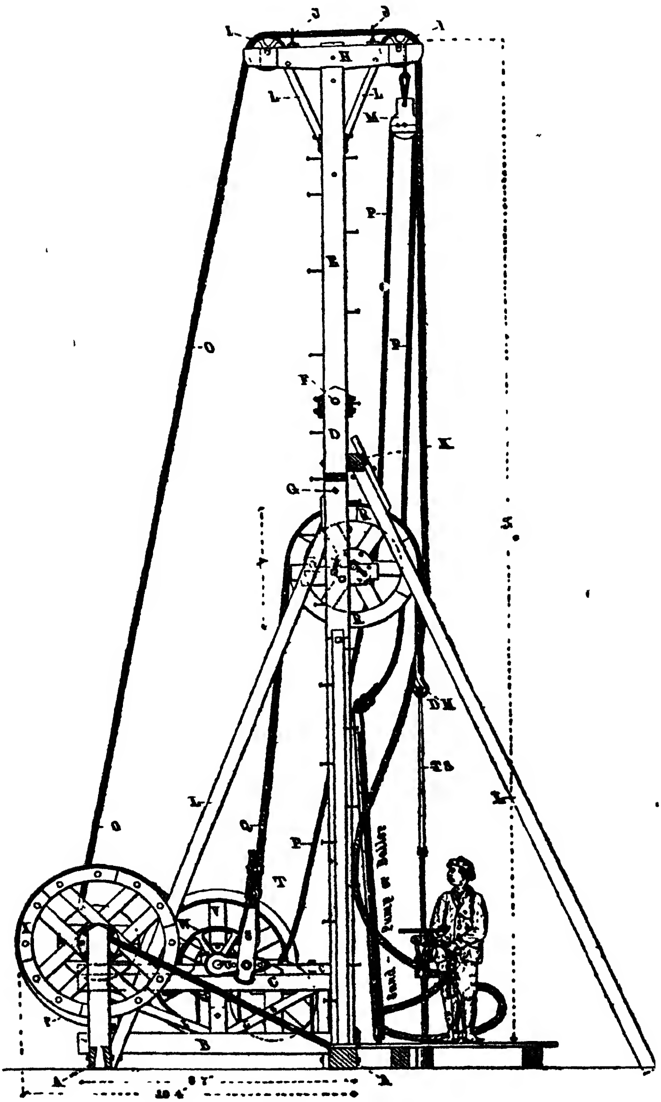


FIG. 64.—PORTABLE ROPE-BORING PLANT.

levers, a view of the rig arranged for pipe-driving, and a view of it arranged for pumping. This arrangement, by the Oil Well Supply Co of Bradford and Oil City, Pennsylvania, U.S A., is highly recommended for wells of a less depth than 600 ft., and can be operated by either steam or horse power. It will swing a set of boring tools 31 ft long and weighing 950 lb. , occupies a space of only 12 by 20 ft. ; weights complete but 2 tons (4000 lb.) , and, when the mast is folded, is 25 ft. high.

The two mud-sills A, one 10 in square and 11 ft 5 in. long and the other 10 by 8 in. and 10 ft. long, rest upon the ground and sustain two beams B, 8 by 6 in in section and 8 ft. 7 in long, which support on proper posts the framework C. The double samson-post D is fastened to the principal mud-sill A, and the mast E is hinged therein at F by a piece of tube passed through both posts and mast. A bolt with large washers is put through the pipe, and a nut and large washer are added At the point G another bolt traverses both samson-posts and mast after the latter is raised into position

On the top of the mast is a pulley-frame H, carrying the crown-pulleys I and the guide-hooks J which keep the drilling-cable O in place. At K is a cross-bar, which ties the tops of the samson-posts D together Braces L are put where needed, and all parts are secured by bolts and nuts, no nails being used.

The sand-pump or shell-pump block M is hung on the crown-beam H ; and a guide-pulley N for the sand-pump line P is attached to the cross-bar K.

The working-line Q passes over the drilling-wheel R, and is firmly fastened to the pitman-block S by being doubled through an aperture therein ; the two ends of the rope are made fast together by the clamps T. The other

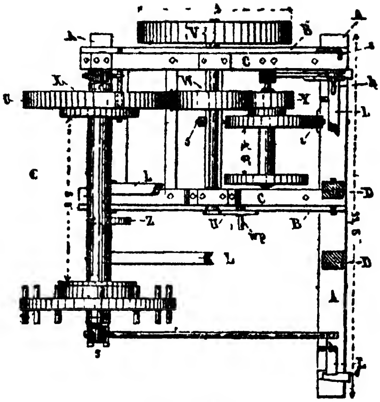


FIG. 66

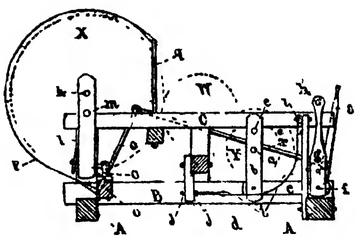


FIG. 67.

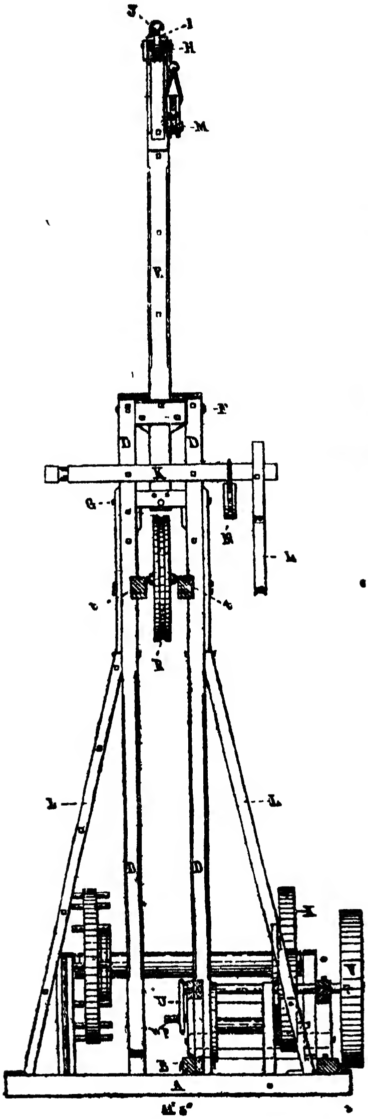


FIG. 65.

PORTABLE ROPE-BORING PLANT.

end of the working-cable is terminated by a drilling-hook D H, on which is hung the temper-screw T S.

The pitman-block S fits in the wrist-pin *w p* of the crank U, and rotation of the crank causes a reciprocating vertical motion of the tools.

Power is communicated from engine or horse-gear to the band-wheel V, on the shaft of which is keyed the friction-wheel W. Either the bull-wheel X or the sand-reel pulley Y is brought against the friction-wheel W as required.

The sand-reel is hung at *a* on the swinging-beam *b*, which is pivoted at *c* to the frame C, and is joined at *d* by the draw-bar *e*, united at *f* to the lever *g*. A pull upon the lever-handle *h* will throw the pulley Y of the sand-reel against the friction-pulley, and this will cause it to rotate and wind-up the sand-line P; while a push upon the lever will cause the wheel of the sand-reel to press against the brake *i*, which is an iron band fitted to encircle a fourth of that wheel Provision is made for tightening that band by nuts at *j*, so as to take up any slack

One end of the bull-wheel X is pivoted at *k* on the swinging-bar *l*, which again is pivoted at *m* to the frame C. A T-bolt unites the swing-bar *l* to the iron lever *o*. This lever has one long arm and two equal short arms with two bearings, the short arms being nearly opposite each other, one projecting above the beam B and the other extending an equal distance below its surface. The swinging-bar *l* is joined to one short arm and the brake-band *p* to the other. A draw-bar *r* connects the long arm of the lever *o* with the hand-lever. The brake-band *p* encircles nearly $\frac{3}{4}$ of the bull-wheel, and is firmly fastened to the rod *q*, which is bolted to the frame C. A pull upon the hand-lever loosens the brake-band *p*, and forces the bull-wheel X against the

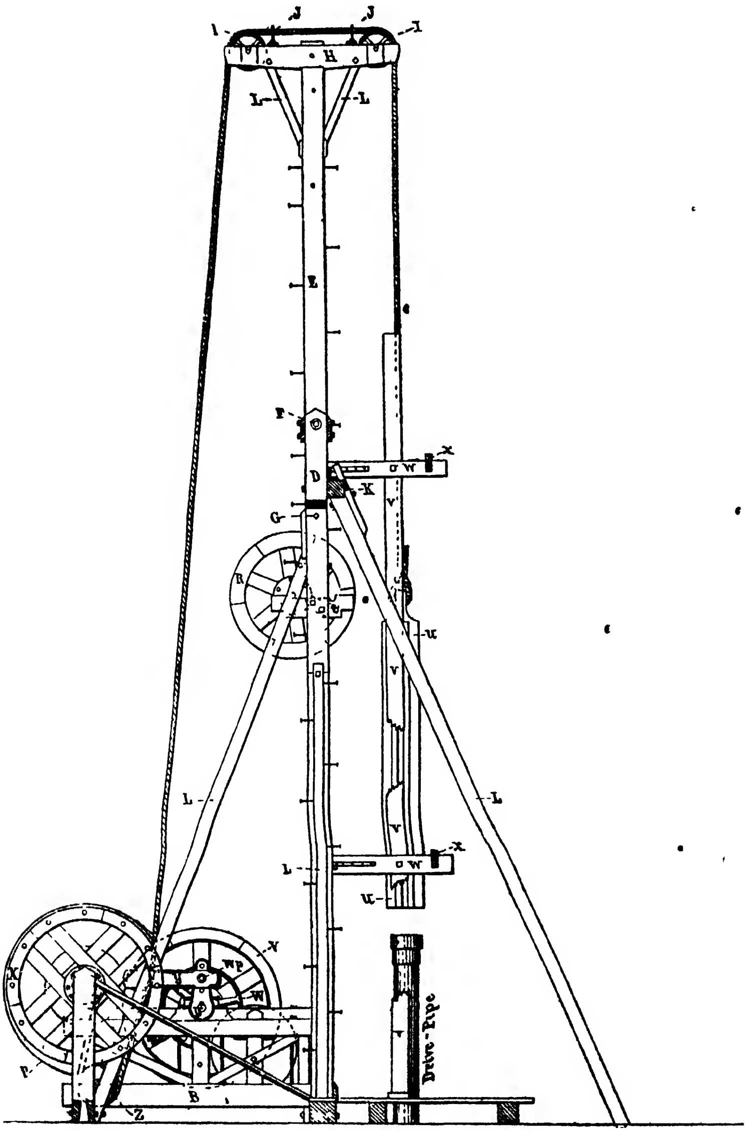


FIG 68.—ROPE PLANT DRIVING PIPE.

friction-wheel W. A push upon the handle *s* forces the bull-wheel away from the friction-wheel W, and clasps the brake-band *p* firmly around the wheel.

The action of the hand-levers *h* and *s* in controlling the motions of the sand-reel and bull-wheel respectively is quick and effective. The bearing surfaces are wide, and the wheels are truly made, so that motion is immediately communicated without the least slip, and the brakes can be applied so as to stop the wheels instantly while at their swiftest speed. When the levers stand straight, both bull-wheels and sand-pump reel revolve freely.

The drilling-wheel R rests in grooves in the supports *t*, of which there are two sets, one in front of and the other behind the samson-posts D When the drilling-wheel R is in use, it rests in the front grooves as shown in Fig. 64; when not in use, it is put in the back grooves.

When driving pipes or using a cutting tool, a small grooved wheel Z is fixed in the centre line of the samson-posts, below the bull-wheel. The cable O is carried downward around the wheel Z and upward over the crown-pulleys I, and is united to the maul *u* which plays in the guides *v* supported by bars *w* hinged to the samson-posts D, the front ends of the hinged bars being kept in position by cross-ties *x*.

A short bar *y* with a grooved wheel at one end, inside of which plays the cable O, is fastened to the wrist-pin *wp*, so as to allow the wrist-pin to turn freely. Rotation of the crank causes alternate tension and loosening of the cable O, and thus the maul *u* is elevated and dropped, much in the same manner as piles are driven.

When the well is pumped, the polished rod has clamped upon it at two points a wire rope which encircles the working-wheel R, and a projecting arm is fastened to that wheel

and connected with a pitman which is attached to the wrist-pin. The mast may be left erect, or folded down as in Fig. 69. The pumping motion is very even and steady,

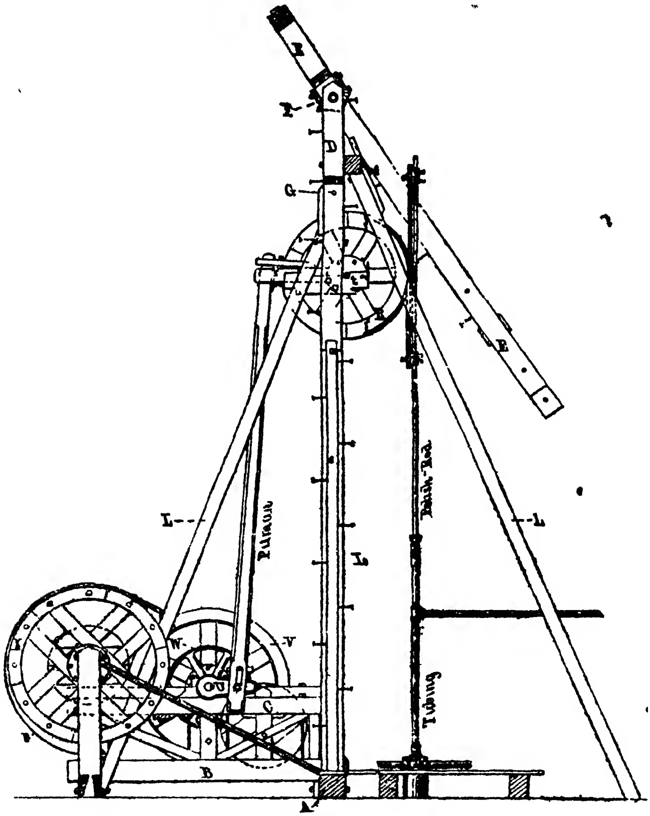


FIG. 69.—ROPE PLANT PUMPING.

as the polished rod moves in a perpendicular line, and saves the tubing from any jar or vibration.

Strong bolts inserted in each side of a brace to one of

the samson-posts D and the mast E form a ladder giving easy access to the top.

The replacing of any wooden part of the rig that may become injured can be effected by an ordinary carpenter.

With fair usage, the rig is reckoned capable of boring hundreds of wells

The first step in the operations is to sink the iron driving-pipe to a depth ranging from 6 to 75 ft. and generally between 20 and 50 ft. This pipe acts as a guide, and prevents earth or stones from falling into the hole while the drilling is going on. The driving-pipe in general use is of cast-iron, 6 to 8 in diam and 1 in. thick, in lengths of 9 or 10 ft. The driving of this pipe is a work of difficulty, requiring the utmost skill, since the pipe must be forced down through all obstructions to a great depth, while it is kept perfectly vertical. The slightest deflection from a straight line ruins the well, as the pipe exerts control over the drilling-tools.

The process of driving is simple but effective. Two slideways made of plank are erected in the centre of the derrick to a height of 20 ft or more, 12 to 14 in apart, with edges in toward each other, the whole is made secure and plumb. Two wooden clamps or followers are made to fit round the pipe, and slide up and down on the edges of the ways. The pipe is erected on end between the ways, and is held perpendicular by these clamps, a driving-cap of iron is fitted to the top A ram is then suspended between the ways, so arranged as to drop perpendicularly upon the end of the pipe The ram is of timber, 6 to 8 ft long and 12 to 14 in. square, banded with iron at the lower or battering end, and furnished with a hook in the upper end to receive a rope When the whole is in position, a rope is attached to the hook in the upper end, passed over the pulley

of the derrick, down to and round the shaft of the bull-wheel. Everything is then in readiness to drive the pipe. The belt connecting the engine and band-wheel being adjusted, and the same having been done to the rope connecting the band-wheel and bull-wheel, called the bull-wheel rope, the machinery is put in motion, a man, standing behind the bull-wheel shaft, grasps the rope which is attached to the ram and coiled round the bull-wheel shaft, holds it fast, and takes up the slack in his hands, thus raising the ram to its required elevation; it is let fall repeatedly upon the pipe, which is thereby driven to the requisite depth. When one joint of pipe is driven, another is placed upon it, the two ends are secured by a strong iron band, and the process is continued as before. The pipe has to be cleared out frequently, both by drilling and by sand-pumping or working the shell-pump Where obstacles such as boulders are met with, the centre-bit is put into requisition, and a hole, two-thirds the diameter of the pipe, is drilled. The pipe is then driven down, the edges of the obstacle being broken by the force applied, and the fragments falling into the hollow created by the passage of the bit. When this cannot be done, the whole machinery and derrick is moved sufficiently to admit of driving a new set of pipes, or the hole is abandoned. It sometimes happens that the pipe is broken, or diverted from its vertical course by some obstacle. The whole string of pipe driven has then to be drawn up again or cut out in the manner already described, and the work is commenced anew. If this is not possible, a new location is sought.

After the pipe is driven, the work of drilling is commenced. The drilling-rope, which is generally $1\frac{1}{4}$-in. hawser-laid cable of the required length (500 to 1000 ft.), is coiled round the shaft of the bull-wheel, the outer end

passing over the pulley on the top of the derrick, down to the tools, and is attached to them by a rope socket, of which various forms are in use. The tools consist of the centre-bit or chisel, auger-stem or drill-bar, jars, sinker-bars and rope-socket, which are shown arranged for work in the order detailed, Fig. 70. When connected, these are 30 to 40 ft. long and sometimes more, weighing 800 to 1600 lb., according to depth required The process of drilling, until the whole length of the tools is on and is suspended by the cable, is slow. When the depth required for hanging the tools is attained, the attachment between the working-beam (or "walking"-beam, as it is often called) and the drilling cable is made by means of a temper-screw depending from the end of the working-beam and secured to the rope by a clamp and set-screw.

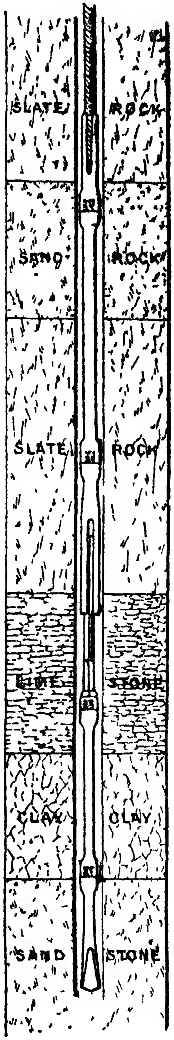


FIG. 70.—SECTION SHOWING AMERICAN ROPE-BORING TOOLS.

The temper-screw *a*, Fig 71, is 5 to 6 ft long and $1\frac{1}{2}$ in diam, with a square thread 2 to the inch. The wrought-iron rims are $1\frac{1}{2} \times \frac{5}{8}$ in. and $5\frac{1}{2}$ ft. long. The nut of the lower end of the rims is cut in two; a band with a set-screw encircles this divided nut, and is riveted to one half, the set-screw pressing against

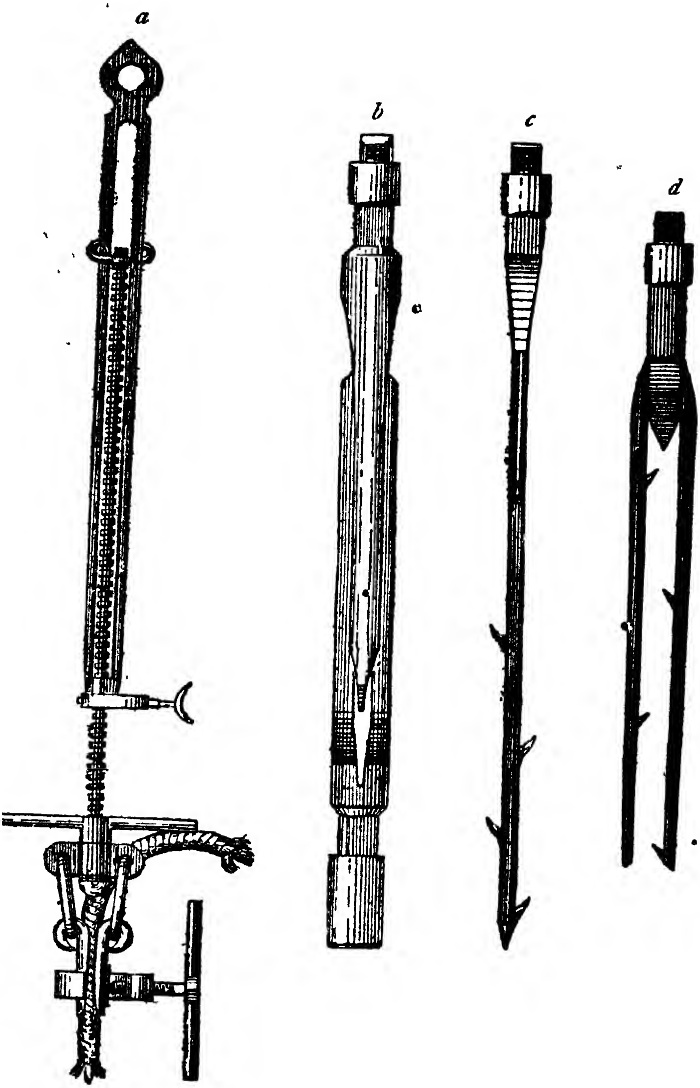


FIG. 71.—AMERICAN ROPE-BORING TOOLS.

the other half. The rims are constructed so as to spring apart and free the nut. When the driller wishes to pay out the temper-screw, he loosens the set-screw and revolves the temper-screw, again tightening the set-screw to maintain it in position. When the screw is all run out and disconnected from the cable, the set-screw is loosened so that the nut flies open and leaves the long screw free, it can then be pushed up, and the nut can be tightened. This adjustment is aided by a counterpoise equal in weight to the screw and clamps, hung on two cords passing over pulleys on the working-beam and attached to the bows of the swivel at the upper end of the screw. One of the pulleys is above the samson-post and the other two are on each side of the drilling-hook The counterpoise moves along the samson-post, and the cords have separate pulleys above the temper-screw, but both go over the same pulley as the samson-post

The "jars" *b* are made in two parts, and are like long links of a chain. Both parts are slotted, and the cross-head of one passes through the slot of the other. When extended, the jars are 6 ft. long, when closed, 5 ft. 3 in.: the difference, 9 in., is the play of the jars, the function of which is to give an upward blow having the effect of loosening the auger and preventing it from "sticking" in the rock.

The rope-spear *c* and the two-wing rope-grab *d* are for taking hold of the end of the rope when it has parted in the bore-hole. At *a*, Fig. 72, is seen a rope-knife in operation, severing the rope in the well.

The combination bit and mud-socket or shell-pump shown in *b* is a most useful tool for clearing out old wells, the bit loosening the dirt so that it can be drawn into the tube for removal. Another form of shell-pump or sand-

pump is represented at *e*, and is known as Moody's; the bailer is driven into the mud by jarring, and the mud is forced into the tube by hydrostatic pressure.

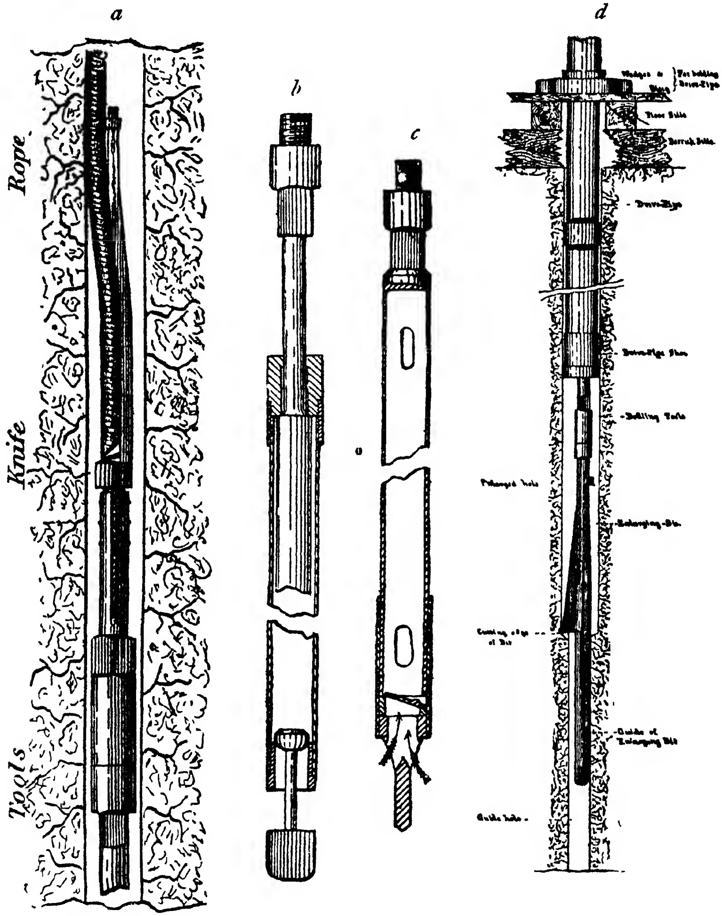


FIG. 72.—AMERICAN ROPE-BORING TOOLS.

The working of Clary's enlarging-bit or rimer (reamer) is shown at *d*. This bit cuts ahead of the drive-pipe, and prepares a hole for it in passing through hard ground. A hole about 4 in less than the outside diameter of the drill-pipe is drilled in advance for reception of the guide-stem of the enlarging-bit. It is a highly effective arrangement.

In drilling, the tools are alternately lifted and dropped by the action of the working-beam on its rocking motion. One man is required constantly in the derrick, to turn the tools as they rise and fall, to prevent them from becoming wedged fast, and to let out the temper-screw as required. This is one of the most important duties of the work, requiring constant attention to keep the hole round and smooth. The centre-bit or chisel is run down the full length of the temper-screw, it is about 3½ ft long, with a shaft 2½ in diam., a steel cutting-edge 3½ to 4 in. wide, and a thread on the upper end by which it is screwed on the end of the auger-stem. The reamer is about 2½ ft. long, and has a blunt instead of a cutting edge, with a shank 2½ in diam terminating in a blunt extremity 3½ to 4½ in wide by 2 in. thick, faced with steel The weight of heavy centre-bits and reamers averages 50 to 75 lb.

The centre-bit is followed by the reamer, to enlarge the hole and make it smooth and round The debris or pounded rock is taken out after each centre-bit, and again after every reamer, by means of a sand-pump or shell-pump The sand-pump is a cylinder of wrought iron, 6 to 8 ft. long, with a valve at bottom and a strap at top, to it is attached a ½-in. rope, passing over a pulley suspended in the derrick some 20 ft. above the floor, back to the sand-pump reel attached to the jack-frame, and coiled upon the reel-shaft.

This shaft is propelled by means of a friction-pulley,

controlled by the driller in the derrick, by a rope attached. The sand-pump is usually about 3 in. diam. Some drillers use two—one after the centre-bit, and a larger one after the reamer: this is preferable. When the sand-pump is lowered to the requisite depth, it is filled by a churning process of the rope in the hands of the driller, and is then drawn up and emptied. This operation is repeated each time the tools are withdrawn from the well, the pump being let down a sufficient number of times to remove the drillings The fall of the tools is 2 to 3 ft. This alternation goes on, first tools and then sand-pump, until the well is drilled to the required depth As a rule, abundance of water is found in the wells, both for rope and tools, from the commencement.

In practical operations, the driller takes his seat on a high stool above the chosen spot, adjusts the drill with great care through the conductor-pipe, and starts striking 30 to 40 blows a minute

Between the strokes the tools require to be moved round. With this also a slight downward motion is given at every few strokes, by a turn of the temper-screw.

The drill is kept moving up and down, cutting 1 to 6 and even 12 in. of rock and shale per hour, according to hardness At intervals the centre-bit is drawn up, badly worn and battered, and a reamer is let down to enlarge the hole and make it smooth and round, these are followed by the sand-pump.

The first few hundred feet are generally gone through without difficulty, provided all the arrangements have been made with care at the beginning, and the drillers are skilful. Difficulties occur farther down that test the most persistent energy.

Sometimes they are attributable to want of caution on

the part of the driller, to imperfection in the material, or improper dressing or tempering of the drill, but more often to circumstances unforeseen and unavoidable. In its passage the drill not unfrequently dislodges gravel or fragments of hard rock, that have a tendency to wedge it fast in the hole, from which it is released only by most persistent "jarring."

The reamer is also subject to the same mishap, or a sand-pump may break loose from its rope, and have to be fished up. When the bit or reamer becomes so firmly imbedded as to render its removal impossible by jarring or by breaking it in pieces, the well is abandoned.

Sometimes a bit or reamer breaks, leaving a piece of hard steel securely in the rock several hundred feet below the surface. Where the fragment is small, it is pounded into the sides of the well, and causes no further annoyance When it is larger the difficulty is greater, and not unfrequently insurmountable. The bit or reamer sometimes becomes detached from the auger-stem by the loosening of the screw from its socket. This difficulty is often greatly heightened by the fact that the workman may not be aware of its displacement, and for an hour or two be pounding on the top of it with the heavy auger-stem. Various plans are resorted to for extracting the fastened tool, and a large number of implements have been devised for fishing it up. The first is an iron with a thin cutting edge, straight, circular or semicircular, acting as a spear, or to cut loose the accumulations round the top and along the sides of the refractory bit or reamer, so as to admit a spring-socket, that is lowered by means of the auger-stem over the top of it, and lays hold upon the protuberance just below the thread

If the socket can be made fast, the power of the bull-

wheel and engine is requisitioned, and in a great number of cases the tool is brought to the surface. In the jarring and other operations rendered necessary in cases of this kind the entire set of tools, 40 to 60 ft. in length, may become fastened, and cases are of frequent occurrence where two and even three sets of tools have become fastened in a well, as they were successively let down to extricate the first ones. This is liable to occur at any stage of the work, and its frequency increases with the depth.

In addition to the difficulties mentioned, there is yet another, far more dreaded by the driller. This is what is called a "mud-vein." It is a stratum of mud or clay, up to several inches in thickness, generally met with at a depth of 400 to 900 ft. Mud-veins abound in most of the oil-producing localities, and not a few operators regard them as invariably indicating an abundant supply. The mud or clay is of a most tenacious character, and while not deemed of much importance as an obstacle in the beginning of the development, may exhibit new features in different localities. The mud suddenly flows into the well while the process of drilling is going on, settling round the drill, bedding it almost as firmly as the rock itself Its presence is often indicated to the driller by the sudden downward pressure on his rope. If drilling on or below it the workman, when about to withdraw his drill, will get assistance from the bull-wheel, and the instant the working-beam ceases its motion, a few turns will be taken on the wheel, so as to raise the bit above the mud, as it sets almost as quickly as plaster of Paris. Sometimes this mud will flow into the hole for a depth of 20 ft. or more, burying the entire drilling-tools and attachments. This renders the jars useless. By attaching a cutting instrument to rods, the rope above the sinker-bar is cut, and then is sub-

stituted a spear-pointed instrument, with which, by means of a light set of tools, the substance round the tools is forced from them, an extra pair of jars is lowered, and efforts are made to jar the tools loose.

The spear is sometimes shaped like a common wedge, faced with steel at the cutting edge, made thin. A half-circular instrument, made in like fashion, is also used The mud-socket, circular shaped with thin edge, terminating on the inside with an abrupt shoulder, corresponds with the ordinary clay-auger, and is similarly used.

A large number of appliances have been invented for the dislodgment of fastened tools, many of them very complicated. The main thing sought is an instrument that in the first place will remove the material round the top of the fastened implements, to be followed by others acting on the principle of a clamp, sufficiently powerful to retain its hold and allow the jarring of the tools loose or the drawing of them up

One most effective instrument for the dislodgment of tools consists of a number of heavy iron rods or bars, similar to an auger-stem, and weighing 10 to 11 tons. It can be made of any desired length or weight. It is lowered over the head of the tools, and these are screwed fast into a suitable socket arranged at the ends of the rods, and worked from the top When a set of tools are fast, each separate piece is unscrewed, the apparatus acting as a left-handed screw Each piece, as loosened, is brought to the surface. By applying the full force of the engine these 2½-in. iron rods are frequently twisted like an auger They are lowered and raised from the top by jack-screws

It will be seen that the system has many features in common with European practice. The centre-bit and reamers are but other names for variously-shaped chisels,

whilst the jars serve a similar purpose to that of sliding joints. As a cheap method of putting down deep bore-holes through shales, limestones and soft rocks, it is very useful; but it must certainly be supplemented by others when hard or troublesome beds are met with.

Elastic Suspension for Drilling-Rods.

M. Petit writes to 'Naphtha' that in the course of drilling a hole with a Canadian rig, he recommended the employment of a spring temper-screw attached to the walking beam, as shown in Fig 72. The screw 1, 80 in. long, was passed through the tapped hub 2, of a horizontal wheel resting on the bearing 3, which was fitted with trunnions 4, 5, engaging in slots cut in the bearing blocks 6, 7, bolted on to the walking beam 8 By means of the wheel the screw could be adjusted vertically to any desired length, the wheel being kept in position by strong pegs, and this simple arrangement gave very satisfactory results.

The owner of the mine where this boring was carried on (M. Laporte) conceived the idea of interposing flat springs between the bearing 3 and the walking beam, in order to diminish the shock to which the string of tools is exposed at each stroke: an arrangement at once enabling the rate of speed and efficiency of the rig to be considerably increased, and at the same time reducing the resistance to be overcome by the engine.

This trial boring, conducted on the water-flush principle, although effected with a Canadian crane, which is little suited to this class of work, nevertheless shows decisively that drilling with rigid hollow rods, through which a strong

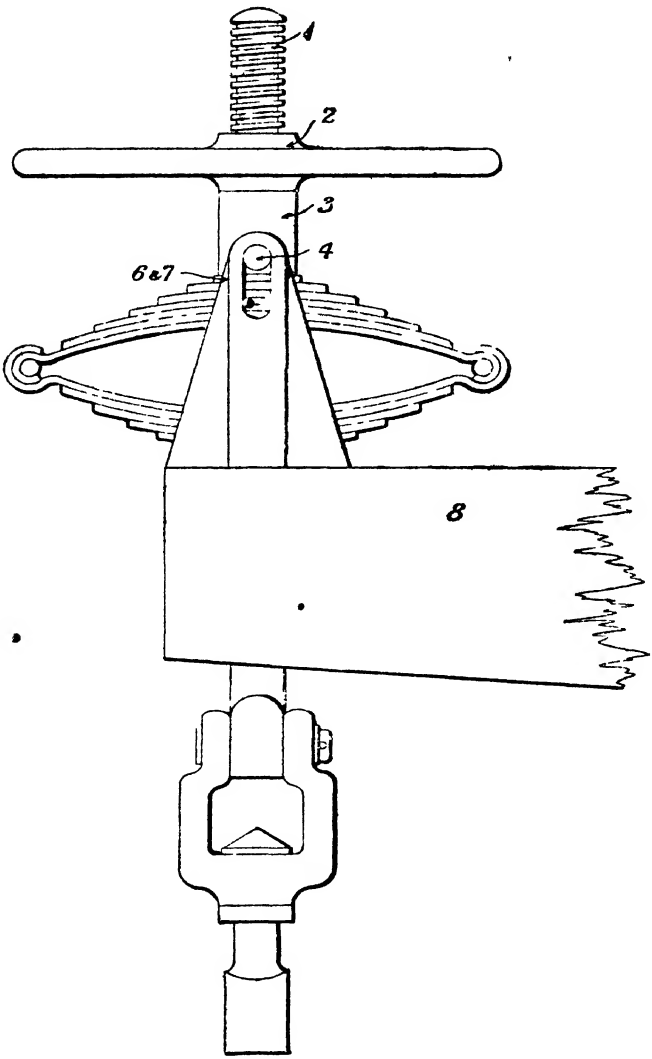


FIG. 72.—SPRING DRILL-HEAD.

current of water is injected to the bottom of the bore hole, is far superior to the ordinary method of drilling with solid rods and jars without a water-flush.

It might have been anticipated that in the oligocene formation at Kobylanka, consisting mainly of compact sandstone, often extremely hard, and rarely interspersed with thin layers of hard shale, the method of drilling with short (3-in.) strokes at high speed (140 strokes per minute) would be surpassed by the method of drilling with long (20-in.) strokes at a maximum speed of 60 per minute. Nevertheless, the contrary was found to be the case. In the sandstone strata, where a rate of progression of not more than 64 in. could be attained in twelve hours by the Canadian method, fitted with the best tools, the rate with the water-flush system was 0.4 in. per minute, 24 in. per hour, or 224 in. in seven hours, nearly three times as great. In compact formations as well as in those of the oligocene epoch the use of the temper-screw with spring, as shown in Fig. 72, enables one to drill as fast with the Canadian crane as by the water-flush method. A trial boring with this arrangement and jars showed that by using a 16-ft. sinking bar, 5½ in. in diameter, with jars of 80-in. stroke, 1-in. rods attached to the temper-screw by a swivel connection, and by working at the rate of 50 strokes per minute, a regular free-fall method of boring can be produced.

At each stroke of the bit the shock of the jars compressed the spring by several centimetres. At the moment when the walking-beam has completed its upward movement a sudden stop occurs. The whole string of tools tends to jump upward, being assisted in that tendency by the springs, which suddenly expand; as, however, the rods are closely attached to the screw, and this in turn to the walking-beam, the bit and sinker bar alone continue this

movement, the rods beginning to descend. In the instant that the walking-beam has completed its down stroke the bit falls freely on to the bottom of the bore hole.

At the speed of 50 strokes per minute the bit works with a 40-in. stroke, half of which is due to the movement of the walking-beam and the remainder to the rebound produced by the sudden relaxation of the spring. Notwithstanding that the jars have a stroke of over 40 in., it often happened that the lower link came in contact with the upper one.

The force of the blow delivered by the bit on the bottom of the hole was surprising, and a rapid rate of progression was maintained, 20 to 23 ft being drilled in twelve hours through strata where the rate under the ordinary method did not exceed 80 in. Owing to the use of a light sinker bar, and the reduction of vibration by the springs, no breakage of rods occurred; the strain on the engine was reduced by one-half, while the rate of drilling was increased two and even threefold, the new method thus affording solid advantages.

The *Hydraulic Washing System* is very efficient and expeditious—it enables drilling through sand, gravel, clay, soft rock, etc., to be carried out very rapidly. It is one of the most efficacious methods as yet introduced.

The boring rods are hollow, so is the borer or chisel; water is forced through the above by means of a steam pump or any other kind available. The rods and chisel are lifted and dropped in a similar way as the ordinary percussion system; as the water is forced through them, the result will be that all the debris are washed to the surface. The great advantage of this system is that the tools need not be removed from the hole from time to time—consequently the ease and rapidity with which they work.

The deeper the boring the greater the weight and the better the work, as the heavier they are the quicker they drop and the faster is the slurry forced up.

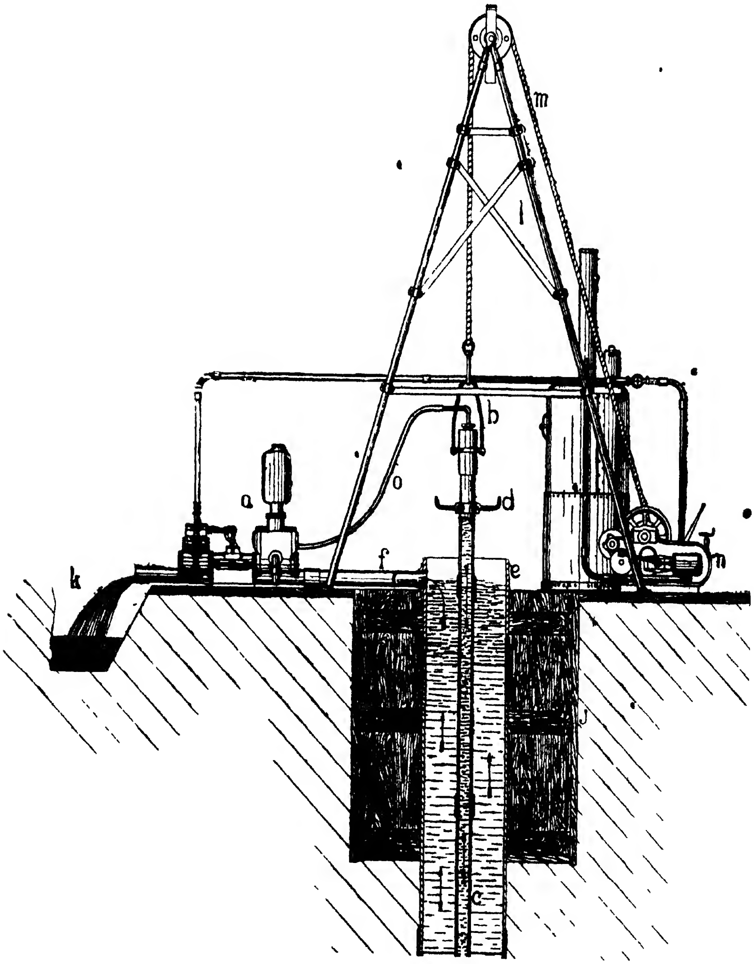


FIG. 73.

It is advisable to sink three or four settling tanks 6 ft by 6 ft and 4 ft. deep, to allow the water and slurry pumped to flow first in one and then the other, the mud will settle, and the water can be pumped over again.

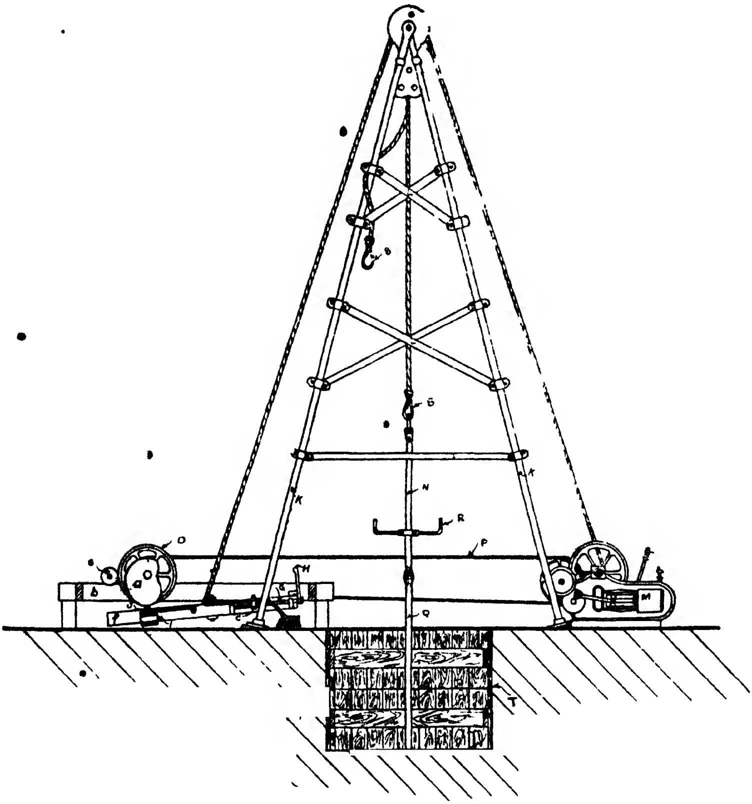


FIG. 74.

The machines illustrated in Figs. 73 and 74 are improved ones; Fig. 74 is an arrangement patented by the author.

With this arrangement the suspension rope supporting the boring rods is attached, through the medium of a screw adjustment, to a lever, which is maintained, by the weight of the rods, in contact with a cam rotated at a constant speed from any convenient source of power, such as a steam-winch. The cam is of such form that the lever is alternately vibrated, with a relatively slow movement, in a direction to raise the boring rods by hauling on the suspension rope, and allowed to return with a quick movement in the opposite direction, so as to permit the boring rods to fall, the depth of the descent being determined by the length of the rope, which is adjusted by varying the position of a nut to which the rope is made fast, the nut working upon a leading screw mounted in bearings on the lever, and rotated by a hand-wheel, ratchet gear, or other convenient means, so as to pay out the rope when a fresh cut requires to be taken. In ordinary hand-punching arrangements, especially in deep borings where the weight of the rods is considerable, great skill and constant watchfulness is required to prevent the tool from striking the bottom of the bore with the full force due to the acquired momentum of the entire boring rods, and so causing them to become bent.

With this machine the length of the suspension rope can be accurately adjusted, so that the tool falls to exactly the same distance on each stroke, thus preventing the rods getting the whole of their own weight and bending, and, at the same time, the cut can be put on with the feed-screw at exactly the required rate, according to the nature of the ground. This can easily be determined by simply watching the punching-rope, and taking care not to feed it forward fast enough to ever allow it to become slack.

Fig. 75 represents a portable rope-boring gear, much

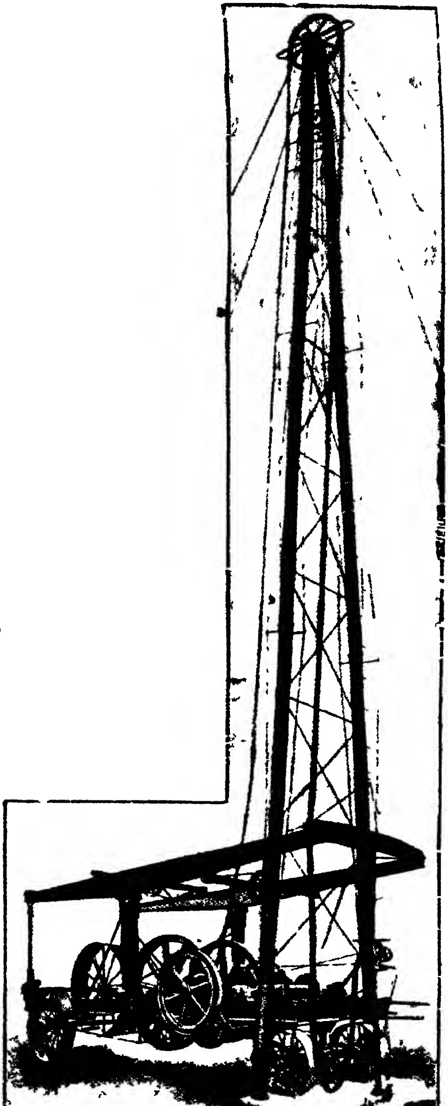


FIG. 75.—PORTABLE ROPE-BORING GEAR.

in use in different parts of the world for reaching small and great depths. The drilling is carried on in a similar way to the American rope-boring system as described on page 131

CANADIAN BORING GEAR.

This system of drilling is by means of ash rods and jars, which are connected to a pumping beam All soils, especially light ones, can be penetrated very rapidly. It

FIG. 76.—CANADIAN BORING GEAR.

is much used for all purposes, whether it be water or oil, and also for prospecting. The working is similar to rope-boring. The bits, or chisels, are made the same shape and form.

CHAPTER IX.

DEEP BORING WITH DIAMOND DRILLS.

ALL the methods of executing a bore-hole to any considerable depth, which have so far been discussed in these pages, involve the complete grinding-up of the removed rock, that it may be discharged from the hole in a condition of sand or mud. While this may be a commendable practice so long as the ground passed through is not of extreme hardness, and neither the depth nor the diameter of the hole is of great magnitude, the converse is the case when those conditions are not present.

It is becoming a matter of serious consideration by advanced mining engineers whether—even in the case of holes only 5 or 6 ft. deep and 1½ in diam. or even less, when the rock is exceptionally hard and resisting to the boring-tool—the principle of pounding to dust the entire contents of the hole can be regarded as comparable in economy with that of merely cutting a thin ring of rock from the circumference of the hole, and extracting the remainder in the form of a solid core.

From a purely scientific standpoint the general smashing principle is obviously inferior to the ring-cutting principle, for it involves an enormously increased amount of work But whereas in the former case the work is done by percussion, with a very simple tool, the latter method depends on abrasion, and the mechanism employed is somewhat complicated and decidedly costly. Even so, with improve-

ments in steel alloys for the necessary tools, rotary core-drills are destined in time to largely replace the ordinary miners' percussive drill of to-day How much more applicable the rotary drill must become in the case of the deep and large bore-holes required in seeking water-supplies from strata lying hundreds of feet beneath the surface need hardly be emphasised.

In another branch of mining, where the desideratum is not so much a hole as the extraction of a solid specimen of the ground traversed, for prospecting purposes, the core-drill is already an indispensable and recognised implement, and in this direction it has gained a wide-spread application. In deep-well boring through hard strata it has been extensively used, and is quite unequalled in efficiency. The deeper the bore and the greater its diameter—in other words, the larger the volume of rock to be removed—the more marked becomes the superiority of the core-drill, but the rock to be penetrated *must be hard.* Herein lies one of the difficulties encountered in core-drilling. A bore of any considerable depth will necessarily pass through various alternations of strata some hard, dense and homogeneous , others of mixed character, such as gravels, conglomerates, and flinty chalk-beds , and, again, others uniformly soft, as sandstones and clays The ordinary core-drill is useless in two out of the three categories, and must then be replaced by the percussive drill The great losses of time and increased expense thus involved have militated against the adoption of the core-drill in well-boring in many cases where sections of the strata absolutely demanded its application. But this drawback has now been entirely overcome by a most ingenious combination machine capable of operating either drill as required, and incurring merely nominal delay in changing from the one to the other ; it will be fully described on a subsequent page.

In its usual form the core-drilling machine is known as the "diamond drill," because the abrasion is performed by an amorphous variety of that gem. They are of two kinds, termed "borts" and "carbonados," which are alike in this that they possess no merit as precious stones and are valuable simply for their hardness. The former occur mostly in the South African deposits; the latter, of Brazilian origin and black in colour (hence their name), are preferred as being more massive and less disposed to splinter In the trade they are called "carbons" A series of these stones are set in a tubular steel "crown" or "bit" attached to hollow rods for rotation at great speed, their number varying with the diameter of the hole to be bored Water forced down from the surface removes the material ground away by the stones, and at the same time keeps them cool The cylindrical core of solid rock is broken off by a special contrivance, and hoisted with the "bit" from time to time. The smallest diamond drills on the market are operated by hand-power, and will take cores of small diameter (about 1 in.) from holes up to 400 ft deep. The largest stock size produces a 4-in. core, and is capable of successful and satisfactory manipulation at the depth of a mile.

The setting of carbons in the bit (Fig. 77) is a matter demanding no little skill and care

After screwing the blank bit into the setting block, the first step is to divide the bit into as many equal parts as the number of diamonds to be used (varying from about a dozen to fifty, according to size of hole), and mark with centre punch, as at *a*, where they are to be placed. Breast-drill and twist-bits are then used to bore a horizontal hole *b* in the side of the bit, each diamond should be studded separately, and a hole be bored in proportion to its size. As the outside diamonds can be more conveniently set than

M

those on the inside rim, the largest should be selected for this purpose, and set first. Horizontal holes are used for the outside diamonds, and vertical holes for those on the inside of the bit. After boring, the hole is chipped out by small chisels until the diamond fits very snugly in the metal as at *c d*, and projects $\frac{1}{64}$ in. above the face, and the same distance from the outside and inside rim of the bit.

When the diamond is fitted in place, and the proper

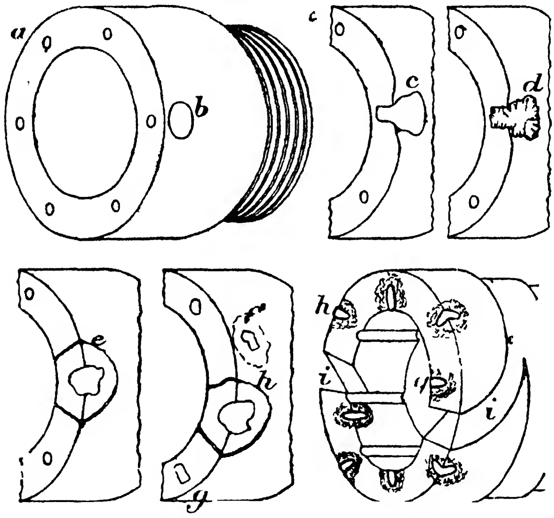


FIG 77 —SETTING DIAMONDS IN BIT.

measurement is obtained, the metal is drawn up or closed round it as at *e*, this is done by first making a cut, with a blunt-edged chisel, across the face of the bit, about $\frac{1}{8}$ in. from each side of the diamond, and all around it on the outer surface, then, by using a dull-pointed chisel or caulking-tool, the metal is gradually driven towards the diamond.

In order to get the diamond placed to the best advan-

tage, it is often necessary to cut away more metal than it is possible to replace by driving up the original metal on the bit; in such cases, thin wedges made of horse-shoe nails or copper wire, hammered flat or wedge-shape, should be used to fill up the space around the diamond before the caulking takes place, many operators prefer to make a bed of copper-foil for seating the carbon in any case. The setter should endeavour to place the diamond in such a position that it will have a sharp cutting edge on the face of the bit, and at the same time leave a broad strong side or surface for the clearance on the outside of the bit, as at *d*, which will obviate much reduction in size of the bit

The diamond should be held in place by the third finger of the left hand, and the chisel or caulking-tool be held between the thumb and the first and second fingers. First drive up the metal on the face of the bit until it holds the diamond in its proper position, then the caulking on the sides can be done. Care should be taken that the diamond does not move from its proper position, thereby destroying the gauge or measurement. When the metal begins to bear on the diamond, a finer-pointed tool should be used; light blows are struck, and the metal is closed in carefully. It is possible to break the diamond by caulking the metal too tightly, and also by driving the metal to fill an opening near the corner of the diamond while the metal may be pressing hard on it at another point; it is, therefore, necessary to drive the metal so that it will be brought to press uniformly all around

When the rock is extremely hard, extra diamonds are set on the outside of the bit, as at *f*; these assist those on the outer edge of the face in maintaining the true diameter or size. All bits should be set so as to be of the same outside and inside diameter as the first one used.

The diamonds are set alternately, inside and outside, as at *g h*: those on the outside cover the outer half of the face, and cut the outside clearance, while those on the inside cover the inner half of the face, and cut the inside clearance for the core to pass up freely.

Some makers fancy a bit with channels cut as at *k*, which are intended to give greater freedom of exit for the mud produced by the machine in operation.

In some important borings executed by Gulland in 1883 the largest crown used was 23 in. diam. (external), and contained 50 carbons having an aggregate weight of over 300 carats. The crown was screwed to the core-tube (see Fig. 78), and the first tube was 22½ in. ext diam, 30 ft. long, and of wrought iron, above it, with a plate between, was a 5-ft. length of tube intended for receiving the coarser particles brought up with the clearing-water The boring-rods were drawn-steel tubes 3½ in outside diam, ⅜ in. thick, and in 5-ft lengths, united by steel collars. The consumption of water in this case was 3500 gal. per hour, but it was mostly clarified by settling, and used over and over again. The power required was 20 to 40 h.p.

Whenever the drill is withdrawn from the hole the bit should be carefully examined, if any of the diamonds are found to be loose, or the die is worn away so as to leave some of them unprotected, the metal should be recaulked around them. When the bit is so badly worn that the diamonds are greatly exposed, they should be cut out and reset in a new blank.

If, while drilling, some of the outside diamonds are chipped, so that the size of the hole becomes reduced, when the next bit is introduced that portion of the hole bored after the diamonds were broken should be re-bored, so as to be the full size of the standard bit, as any attempt to

force the new bit down into the reduced hole, by trying to turn the rods with tongs or otherwise, will surely destroy the outside diamonds.

To remove diamonds from an old bit, file a cut across the face of the bit, about $\frac{1}{8}$ in. from each side of the diamond, then chisel the metal back and chip it away until the diamond can be forced out by light taps of the hammer on a small copper rod.

Sometimes carbons are dislodged from their setting, generally through applying too much pressure when passing through hard broken rock. This should be detected by an experienced drill-hand from the sound produced. The dislodged carbon must be recovered as soon as possible, because not only does it impede the work of the drill, and in itself constitute a serious loss, but it may easily cause unseating of the remaining diamonds To recover lost carbons, a wad of wax or tenacious clay is placed on the end of the drill-rod; this is gently forced into the hole to its extreme limit, and as gently withdrawn.

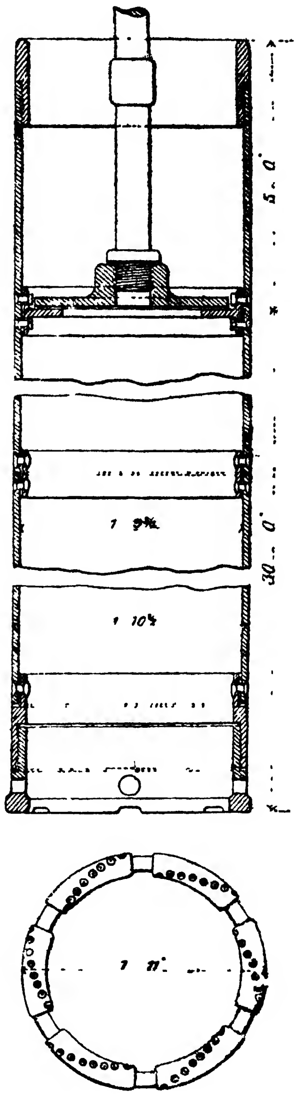


FIG 78.—GULLAND'S BIT AND TUBE.

The best diamonds are the black amorphous "carbonados" of Brazil, especially those of compact form with well-marked corners. Next to them rank the borts or imperfect gem stones of South Africa. Size may vary between 1 and $3\frac{1}{2}$ carats, according to the bit in use, perhaps the most common is 2 to $2\frac{1}{2}$ carats Sometimes pieces of corundum, and sapphires which are valueless as gems owing to opacity and bad colour, are coated with graphite and sold as carbons, they accomplish a double fraud, being both heavier (sp. gr 4 against 3 5) and less hard.

Occasionally delays are caused by breakage of rods, either a fracture of the collar or a stripping of the thread. The remedy is to affix to the upper length a "tap," either in bell form for putting on an external thread, or in plug form for cutting an internal thread, and thus to draw the broken part to surface and replace it

In deep drilling, it is of great importance to have the core-barrel of sufficient length to avoid frequent lifting as it fills. Height of derrick also influences rate of progress, and should not be less than 50 ft., in order that 40-ft. rods may be unscrewed at a time, this being a maximum convenient length with rods of 2 in. diam Area of brake surface must be ample, or much delay will be caused by heating.

Electric motors present special advantages for working diamond drills, and have been largely used for that purpose both at surface and underground A drill working a 2-in hole, and bringing up a $1\frac{3}{8}$-in core, capable of drilling easily to a depth of 600 ft, can be driven by a $2\frac{3}{4}$-h p. motor, the whole arrangement being compact in the extreme, and suitable for underground or awkward situations where steam could hardly be used. The rapid rotation of the

diamond drill adapts it particularly to electric driving. But the great majority operating in well-boring are run by steam.

Owing to the increasing cost of carbons for boring, the "calyx" drill (which has revolving steel cutters) is coming much into favour. A contrivance for adjusting the driving mechanism of the diamond drill to suit the calyx cutter, so as to make the one machine interchangeable and save enormously in first cost of plant, has been invented by Mr. E Williams, superintendent of diamond drills in Victoria, and adopted by the Victorian Government. It consists of a simple intermediate gear for reducing the speed in a ratio of 19 to 1, and can be thrown in or out as required.

The combination machine for both percussive and core-drilling is shown in Fig 79 It is the invention of Mr C Isler, and its use is monopolised by his firm Mounted on wheels and made to take apart, it is exceedingly portable and can be applied in almost any situation Its consumption of water is ordinarily about 700 gal per hour for clearing-out purposes, but in traversing non-absorptive strata this is much reduced. Moreover, by settling, the water is rendered fit for repeated use. The machine once placed, it remains a fixture until the hole is finished or abandoned, no matter how many alterations of hard and soft ground may call for change of tools These changes are made in the space of a minute or so without any derangement of the gear.

The special tubing described on p 64 is always to be recommended for lining the bore-hole

Various conditions govern the supply furnished by a well. It may be delivered under such hydrostatic pressure that it will flow readily from the top of the bore, and even

in some instances will be forcibly ejected considerably above it ; and it may require to be pumped, notwithstanding that the volume suffers no diminution by that operation. But cases sometimes occur where no supply appears to be available, despite the fact that the bore is known (from

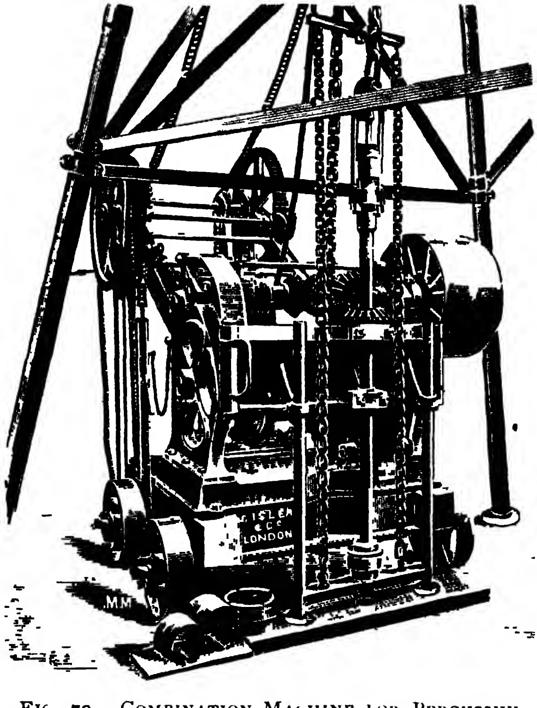


FIG. 79 —COMBINATION MACHINE FOR PERCUSSIVE AND CORE DRILLING.

examination of the core or débris) to have entered a water-bearing stratum. In this event it would be premature to regard the hole as dry. When boring for petroleum it is indeed a somewhat common experience, and is due to lack of such fissures and joints in the rock as will afford a suffi-

ciently free passage of the fluid from surrounding territory towards the bore-hole.

This failing is remedied by the explosion of a "torpedo" at the bottom of the hole. It consists of a tin canister of suitable dimensions—sometimes the longer the better—filled with a nitro-glycerine compound, such as Nobel's blasting gelatine, primed with a detonator, lowered to the point at which it is to be fired, and discharged by a conductor leading from a small electro-magnet machine. The effect of the very forcible explosion is to thoroughly disturb the adjacent rock, and to very much extend any existing line of fissure Some remarkable results have followed from torpedoing. At a well near Rochester, 15 in. diam. and 300 ft deep, in compact rocks of the Lower Greensand formation, which refused to yield any water at all when finished, after explosion of an 18-lb. torpedo a flow of 20,160 gal. per hour was started, and this has been constantly maintained ever since Another example may be quoted of a $7\frac{1}{4}$-in. well, 363 ft deep, at Gloucester, the effect of firing a single shot may be seen in the frontispiece.

Of the hundreds of wells bored in England, perhaps the most remarkable is that at Bourn, Lincolnshire, which supplies the town of Spalding It was sunk by C Isler & Co, in the Oolitic beds, and at 100 ft. it furnished a flow of 1800 gal per minute at a pressure of 10 lb. to the sq. in., reaching the surface with a rush as depicted in Fig. 80, on continuing the bore for an additional 34 ft. the flow was increased to 3480 gal per minute, and has permanently remained at this figure. The well is 13 in diam. At about 66 ft. from surface, springs of chalybeate water were encountered, but these were successfully and completely excluded by the lining-tubes. These last are in three series first, 10 ft of 22-in. pipe passing through clay and

entering the limestone; inside them, commencing a little higher above the surface, 32 ft of 18-in. tubes, reaching to

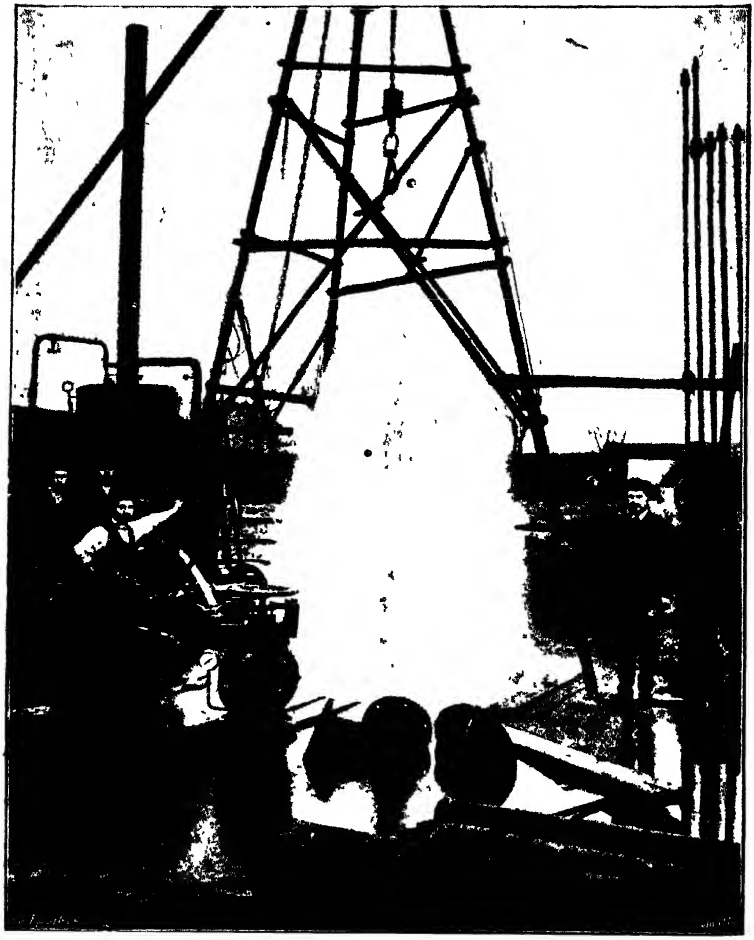


FIG. 80.—THE BOURN WELL.

the hard blue rock of the Oolite ; and finally, again inside and standing somewhat more out of ground, 73 ft. of 13-in., just penetrating into the absorbent stratum, below which point the bore is not lined. The annular spaces between the respective series of pipes are closely filled with a specially-prepared cement, to effectively resist the pressure of (and thereby exclude) the springs of undesirable water from the upper strata

Another remarkable well bored by the same firm is at Keighley, Yorkshire. It is 250 ft. deep, in the upper beds of the millstone grit, and at 243 ft it tapped a supply of 15,000 gal. per hour, rising to 40 ft above the surface. It is lined with 60 ft of 6-in tube starting from 1 ft. above ground, and 40 ft of 5-in. perforated tube commencing at 60 ft. below the surface , beyond that it is not lined

In Tables I and II. are given some details of earlier wells at Northampton.

TABLE I

BORING AT KETTERING ROAD, NORTHAMPTON.

Diam of Crown	Depth Drilled	Number of Days Drilling and Extracting	Average Depth per Day		Nature of Strata	Diam of Core	Ratio of Core Extracted
in	ft		ft	in		in	%
23	77	17	4	$6\frac{1}{2}$	Lias Clay	$19\frac{1}{4}$	
$20\frac{1}{2}$	97	15	6	$5\frac{1}{2}$	,,	$16\frac{3}{4}$	.
18	106	16	6	$7\frac{1}{2}$	,,	$14\frac{1}{2}$	.
$15\frac{3}{4}$	55	11	5	0	,,	$12\frac{1}{4}$	.
,,	68	10	6	9	Sandstones and marls	,,	95
,,	25	15	1	8	Quartzite	,,	100
,,	20	5	4	0	Limestone and shale	,,	98

TABLE II.

BORING AT GAYTON, SOUTH-WEST OF NORTHAMPTON.

Diam of Crown	Depth Drilled	Number of Days Drilling and Extracting	Number of Hours Drilling	Average Depth Per Day		Average Depth Per Hour		Nature of Strata	Diam of Core	Ratio of Core Extracted
in	ft			ft	in	ft	in		in	%
18	125	11	104	11	4	1	3	Lias clay	14½	88
15¾	148	3	127	11	4½	1	2	,,	12¼	90
13⅝	182	17	183	10	8½	1	0	,,	10¼	92
11⅞	117	10	100	11	8	1	2	,,	9¼	88
,,	63	8	60	8	0	1	0½	Red marl and sandstone	,,	64
10⅛	215	25	213	8	7	1	0	Lower Carboniferous Limestones and shale	7	84
								Sandstones	,,	68

Of wells recently bored in the London basin by the author 12 have a depth of less than 300 ft., 22 range from 300 to 350 ft, 18 from 350 to 400 ft., 9 from 400 to 450 ft., and 2 exceed 450 ft. The flow is not less than 1000 gal. per hour in any instance, whilst in 2 cases it amounts to 2000 gal., in 11 to 3000, in 14 to 4000, in 7 to 5000, in 2 to 6000, in 5 to 7000, in 5 to 8000, in 7 to 10,000, in 4 to 12,000, in 1 to 14,000, in 1 to 20,000 and in 1 to 35,000 gal. per hour.

The working costs of diamond-drill bores are subject to very wide variation, dependent upon hardness of rock, delays through accidents, rates of wages, prices of carbons, and so on. The following exemplifications are quoted from Warnford Lock's *Miners' Pocket Book*,* and though they

* Published by E and F. N Spon, Limited

refer in all cases but that of New South Wales to prospecting bores for mineral deposits, and in no instance embrace the item of lining-tubes, they are most instructive as referring to our Australian and South African colonies where the need of water is severely felt, and where deep wells must be largely resorted to in the near future:—

"Official reports on diamond drilling in New South Wales state the cost at 30*s.* 4*d.* per ft in 1895, and only 11*s.* 5*d.* in 1896, the difference being due to shallower work and easier ground. The cost of carbons per ft bored has varied remarkably, thus —1883, 3*s.* 8*d.*; 1884, 2*s* 1*d*, 1885, 1*s.* 5½*d*, 1886, 8¾*d*, 1887, 1*s.* 7*d.*; 1888, 1*s.*; 1889, 1*s* 3*d.*, 1890, 7¼*d.*; 1891, 1*s.* 10*d*, 1892, 2*s* 2*d*, 1893, 3*s.* 3¾*d.*; 1894, 9*d*, 1895, 3*s* 9½*d.*, 1896, 2*s.* 1¼*d* The actual working cost per ft. in 1895 for a 4-in. bore 299 ft deep in porphyry was 15*s.* 2*d.*, the rate of progress was 9·34 in per hour, and the core obtained was 87·6 per cent

"South African figures are quoted by several authors. Denny states the average at 18*s* per ft., on an assumption of 100 ft a week, and paying drill hands 20*s.* a day, labourers 2*s.* 6*d*, fuel at 20*s.* a ton, and carbons at 150*s* a carat. He says contractors charge 25*s* per ft for first 100 ft., rising 5*s* per ft for each 50 ft

"Truscott put down 8 holes, of an aggregate depth of 2686 ft, at a cost of 36*s.* 6*d.* per ft One of these holes, having a depth of 597 ft, averaged 19 9 ft. a day, 1⅜ in. core, and used 8 h p motive force and 1440 gal water daily, the contractor was paid 30*s.* a foot for 500 ft, and 35*s.* for 97 ft., and the cost of water supply (74*l.* 18*s* 6*d*), core watcher (40*l.* 12*s.* 6*d*), hire of drill (50*l.*), and sundries (29*l* 5*s.*), was equal to 6*s* 6*d.* a foot.

"The Bezindenville bore, sunk by Chalmers, occupied

212 days, with an average of 17·58 ft per diem, external delays accounting for 12 days. For the first 2000 ft. the crown was $2\frac{3}{4}$ in. and core $1\frac{7}{8}$ in diam., and for final 1728 ft., 2 in. and $1\frac{3}{8}$ in. Delays incidental to drilling, repairs, loose carbons, etc, totalled 55 days, or 27 per cent. on 200 days. On 145 days' straightforward drilling the rate was 25·7 ft. per diem. The time lost in raising and lowering rods was over $\frac{1}{3}$ of the whole There were used 360 carats of carbons or between 8 and 9 carats per 100 ft, which at 80*s.* per carat = 7*s* per ft.; wages, including overseer, came to 7*s.* 7*d.* per ft, coal, 260 t., at 20*s.* = 1*s* 1*d.*, and sundries came to 9*d.*; or a total of 16*s.* 5*d* per ft, plus interest on 3000*l.* worth of plant.

"According to Wybergh, contract prices vary from 22*s.* 6*d* to 40*s.* a foot, being usually constant for first 100 ft., and rising 5*s* per ft. for each 500 ft. Carbons range from 7*l.* to 13*l* per carat On 14 bore-holes put down by contractors, aggregating 7962 ft, the mean cost was 31*s.* per foot, the range being from 25*s* 6*d.* to 40*s.*, in addition, water cost nil to 15*s*, average 5*s*, superintendence, 6*d.* to 7*s.* 6*d*, average 2*s.* 6*d*, and sundries, 4*d.* to 1*s.* 1*d.*, average $9\frac{3}{4}$*d*, making the total 28*s.* 3*d.* to 51*s.* $10\frac{1}{2}$*d.*, average 39*s.* $3\frac{3}{4}$*d* per foot. The water consumption fluctuated between 1300 and 3200 gal. per diem. The rate of boring was 6·38 to 55·27 ft. per diem, and averaged 16·25 ft. per diem, or 0·89 ft. per hour With contractors the wear of carbons cannot be ascertained, but in another bore of 1328 ft. in quartzite, somewhat more difficult than the average ground, the consumption was 6·92 carats per 100 ft. In this instance the detailed cost was:—Carbons, 9*s* $9\frac{1}{2}$*d.*; hire of drill, 3*s* $1\frac{1}{2}$*d.*; labour, 11*s.* $5\frac{1}{2}$*d.*; coal, 1*s.* $5\frac{1}{2}$*d.*; stores, $11\frac{1}{2}$*d*; superintendence, 1*s.* 3*d*; sundries, 6*d.*; total, 28*s.* $6\frac{1}{2}$*d.* per foot In 3 holes put down by a

hand drill, aggregating 318½ ft., through quartzite and diabase, the average rate was 2·03 ft. per diem, or ·309 ft. per hour, and the cost was —Hire of drill and wages of superintendent, 11*s.* 3*d.*, wear of carbons, 10¾*d.*; labour, 4*s.* 10*d.*; sundries, 1½*d*; total, 17*s* 1¼*d.* per foot."

Improved Combined Rotary Shot Boring and Percussion Boring Plant

The method of boring with hard chilled-steel shot is not of recent date, but it is only of late years that it has

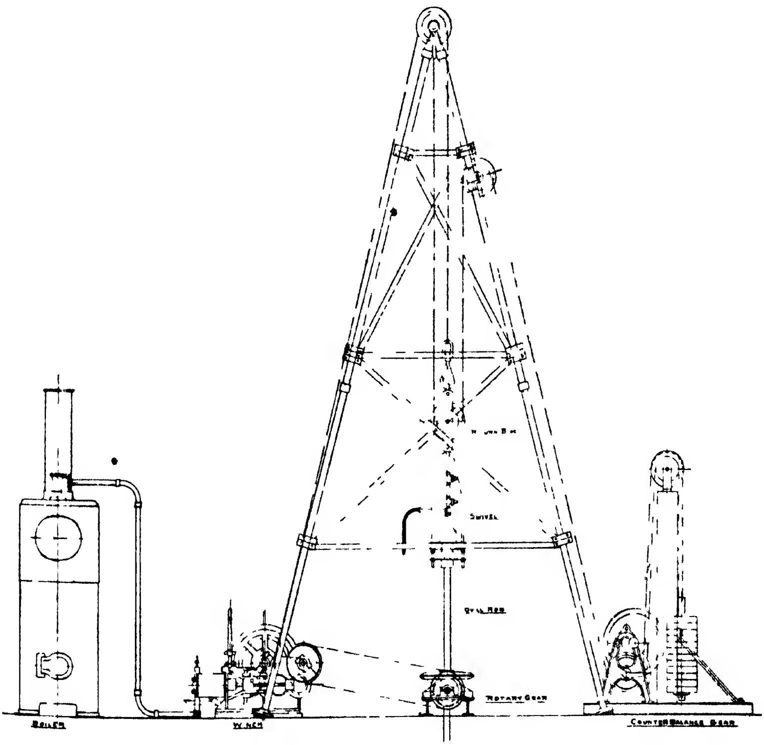


Fig 81

become a common practice among some of the firms who are connected with the mining industry to employ it.

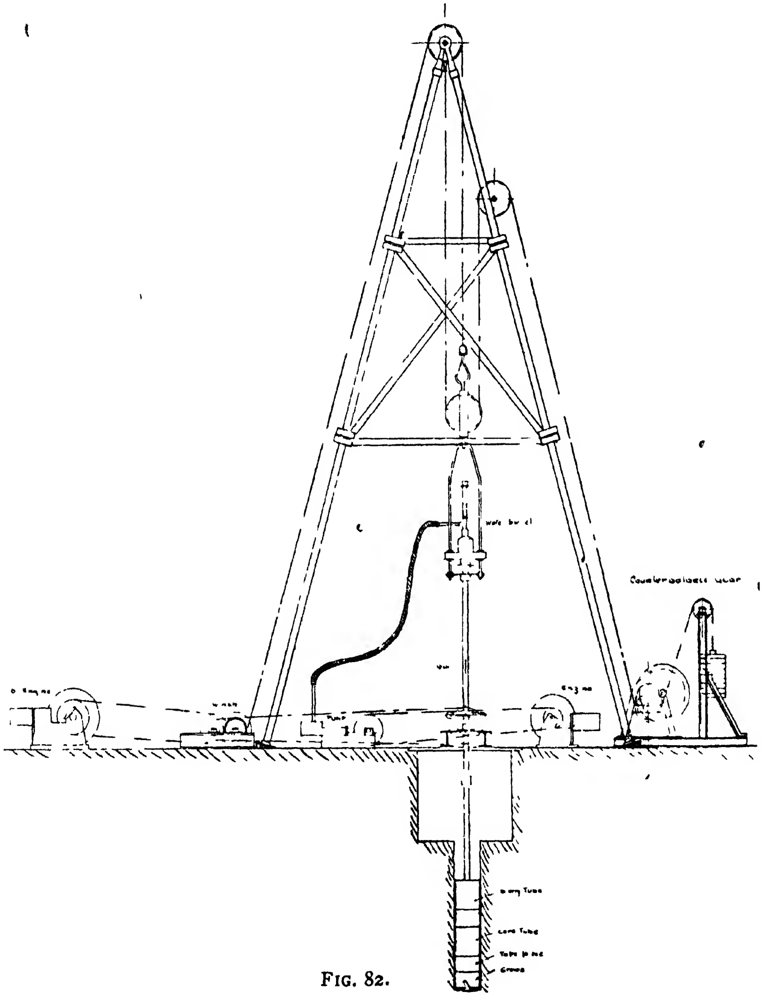


FIG. 82.

Considerable improvements have been made in this line, which ensure the hardest of rocks to be penetrated with

ease, accuracy, and as rapidly, if not more so, than by the diamond drill.

The drill is similar in construction to the diamond drill, with the exception that the crowns are of plain steel,

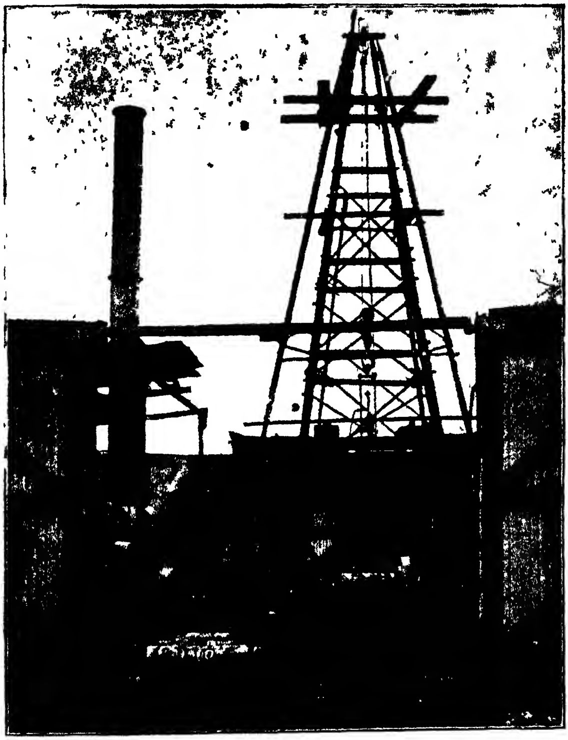


FIG. 83.

the shot being fed through a specially designed hollow swivel head, and through the hollow boring rods to underneath the plain boring crown, which rests on the bottom of the bore. The rotation of the crown causes the shot to rub

a path for it to travel in when it allows the core to enter the core tube. The length of the core obtained depends entirely upon the nature of the rock which is being drilled. If the formation is a solid one with few fissures, and not in any way friable, it enables a long core to be extracted, in accordance, of course, with the length of the core

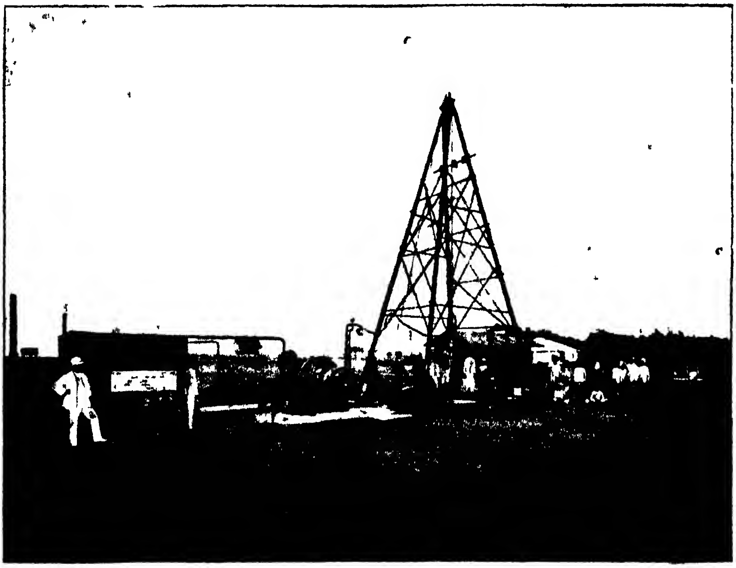


FIG. 84.

tube. The core tube can be made any length practicable. The advantages to be obtained by this combined system over any other as yet introduced, whether it be by the common percussion drilling with solid rods of iron or wood, or any of the rope-boring systems, are very considerable, as it ensures greater speed and reliability as regards the perpendicularity of the boring in drilling

through soft or hard strata, whether they be fissured or hollow.

It supersedes diamond drilling because the cost of the boring with diamond drills has become prohibitive, owing to the great cost of the diamonds—especially the carbon, which is unapproachable. It would cost thousands of pounds to be expended if any reasonable diameter of core were required.

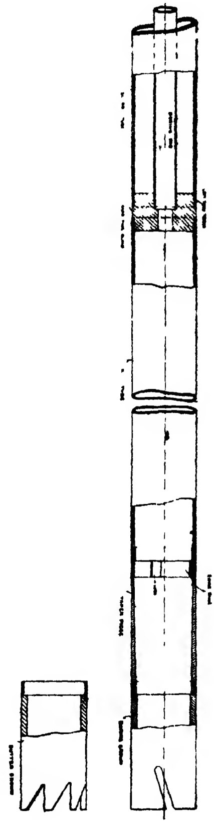


FIG. 85

The depth of the bore-hole it is intended to reach regulates the diameter it should be commenced with. If it be a great depth, the larger the diameter the better, as the cost of a larger plant is only a second consideration, when the results looked for are considered. I certainly do not advise small diameter bores to reach a great depth, as many failures have been caused through such means It leaves no room to reduce, if the geological formation proves of a variable nature.

The combination of this system is that plain and teeth crowns can be used through hard and soft rocks, and if soft clays, sands, or any other friable soils are met with, it enables the hydraulic washing system to be used, by simply employing hollow chisels which can be fitted to the same rods, and the same plant can be employed to continue the drilling, hence the description of "improved combined rotary shot and percussion boring plant."

Fig. 81 represents combined rotary shot and percussion steam driven plant.

Fig. 82 represents combined rotary shot and percussion oil-engine driven plant.

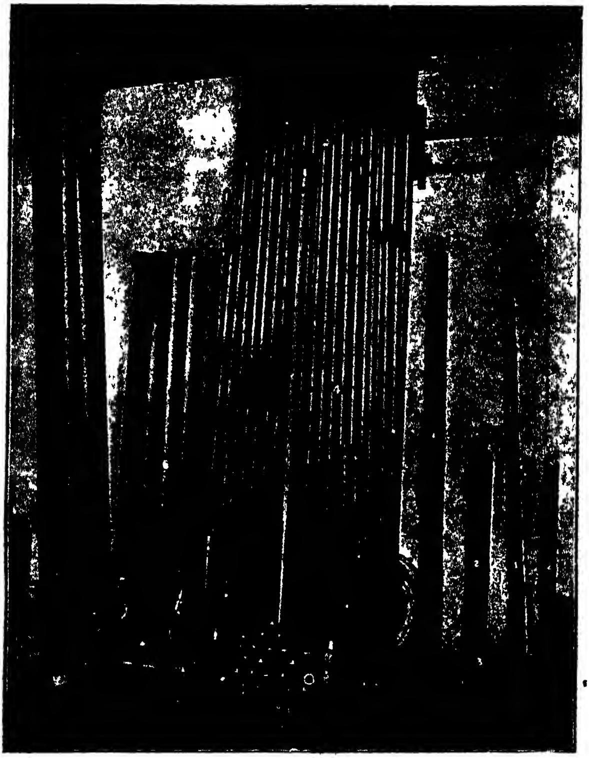


FIG 86.—1, Core Tube; 2, Slurry Tube; 3, Crowns; 4, Boring Rods; 5, Water Chisels; 6, Lining Tubes.

Fig. 83 represents combined rotary shot and percussion oil-engine driven plant for 2000 ft. or more.

Fig. 84 represents combined rotary shot and percussion plant for 2000 ft. or more, fixed in India.

Fig. 85 represents boring tools for shot core boring through hard and soft formations.

Fig. 86 represents crowns, chisels, rods, etc.

FIG. 87

Fig. 87 represents cores from a 2000-ft. bore-hole—diameter of cores when starting 24 in., and 14 in. diameter at 2000 ft.—still in progress

PLATFORM BORING GEAR.

The platform boring gear, as per Fig. 88, is quite of recent introduction, and is being used largely for prospecting for gold and other purposes, when only shallow borings are required.

The chief system on which this boring gear is based, is that the weight necessary for sinking the lining tubes is obtained by the actual operation of boring being carried

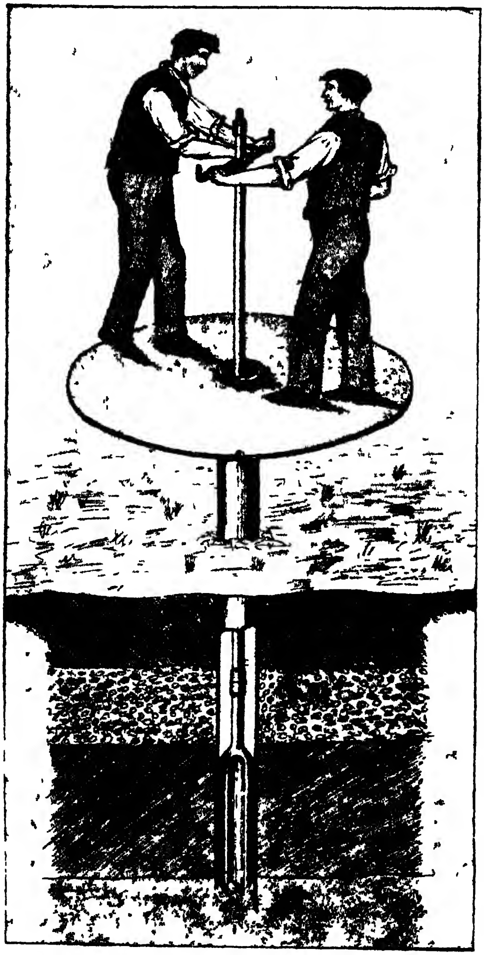


FIG. 88.—PLATFORM PROSPECTING BORING PLANT.

out on a platform placed on top of the projecting part of the bore-tube, this platform being removed when a new length of tube is connected.

The boring and sinking of the tubes are carried out simultaneously, which is a great advantage in saving time lost with other designs of boring plants whilst tubes are fixed into position.

When prospecting in soil containing gold or ore, when an absolute accurate sample of the stratas is required, the extracting tools must never project beyond the bottom of the bore-tubes, which ensures only samples of the actual soils penetrated being obtained and their depths located, without fear of being mixed with soils near the surface.

The chief advantage of this plant is that it is possible to bore in marshy soils without a ground platform, and in swamps and shallow waters with light platforms for the ground men to walk on.

To start the bore-hole the soil is first bored out with the auger or drill, great care being taken to keep the bore-hole vertical

When it is required to insert the lining-tube the first length is provided with a cutting shoe, which can have either a plain cutting edge or a saw edge.

The boring can be carried out with two or more men on the platform, and two or more men on the ground rotating the tubes with levers This system is much used on the West Coast of Africa, where blacks are employed to weight the platform to increase the speed of the work.

The tools mainly used with this plant are augers, sand pumps or shells, and chisels for loosening soils.

DOUBLE GEARED BELT-DRIVEN BORING WINCH.

The construction of this winch is especially designed for drilling purposes, and for export. It is powerfully built, and combines lightness with strength. It is so arranged with fast and loose pulleys that it is adapted to be driven by any kind of engine (Fig. 89).

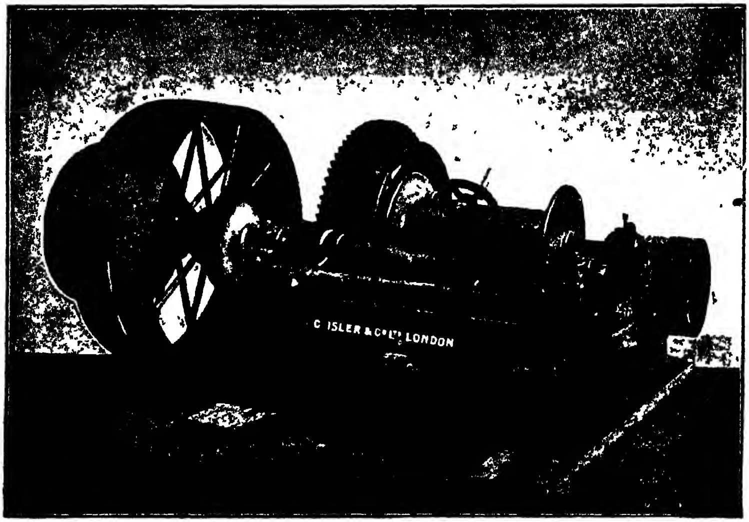


FIG. 89.—DOUBLE GEARED BELT-DRIVEN BORING WINCH.

CHAPTER X.

RAISING WATER

THOUGH cases have been cited where deep bores have resulted in a constant stream of water being ejected to and even above the surface of the ground, in the great majority of instances this does not occur, and after the water-bearing strata have been pierced the level to which the water will rise is at some depth below the surface. For example, the general rule in the London basin is that in tube-wells 400 ft deep the water level is 100 to 200 ft from the top Some form of pump or lift must therefore be employed to raise a supply But inasmuch as the water level is dependent upon the horizon at which the intake of rain-water occurs, it remains constant, notwithstanding the rate at which supplies are withdrawn from the well. In fact, it much more commonly happens that the water level is raised than lowered by pumping, as the operation tends to reduce the pressure upon the underground reservoir and to render the conduits more free.

While it would be inconvenient and out of place in this volume to attempt a description of, or even to catalogue, the multifarious forms of pump, from the common domestic article costing a few shillings to the highly complex pumping-engine installed at an outlay of several hundred pounds, a few paragraphs may properly be devoted to that branch of the subject which embraces more particularly the most

modern and approved appliances connected with deep tube-wells.

In country districts, whether the supply be needed for irrigation of crops or for watering stock, too much attention cannot be given to the utilisation of the wind as a motive power for actuating the pump. There are practically no places where a certain amount of wind cannot be counted on at all seasons of the year, and no source of power is so cheaply applied, and the fact that an elevated site for the well is often desirable, so as to secure distribution of the water by gravitation, makes the application of the windmill all the more convenient and satisfactory.

In towns, the employment of the "air-lift" system has much to commend it Though comparatively unknown in England, it is most extensively used in the United States, where it was invented, and its merits are being rapidly recognised in Continental Europe. Its advantages lie in its simplicity and in the entire absence of working-rods in the bore-hole, thus avoiding all possibility of derangement and hindrance to supply, as well as the jar and noise incidental to pumps. The water is made to flow in a gentle stream, free from pulsation, by the force of a column of air under great compression.

A recent example of the installation of the author's system at Hyde Park Court Mansions, Knightsbridge, is worthy of illustrated description. The well is 10 in. internal diameter, and is bored to a depth of 450 ft. through the London clay and various sand-beds into the chalk and flints, which are reached at a depth of 284 ft. from surface. The depth which the well descends into the chalk is therefore 166 ft. All the upper part of the boring is lined with a 10-in. internal diameter steel tube, which is

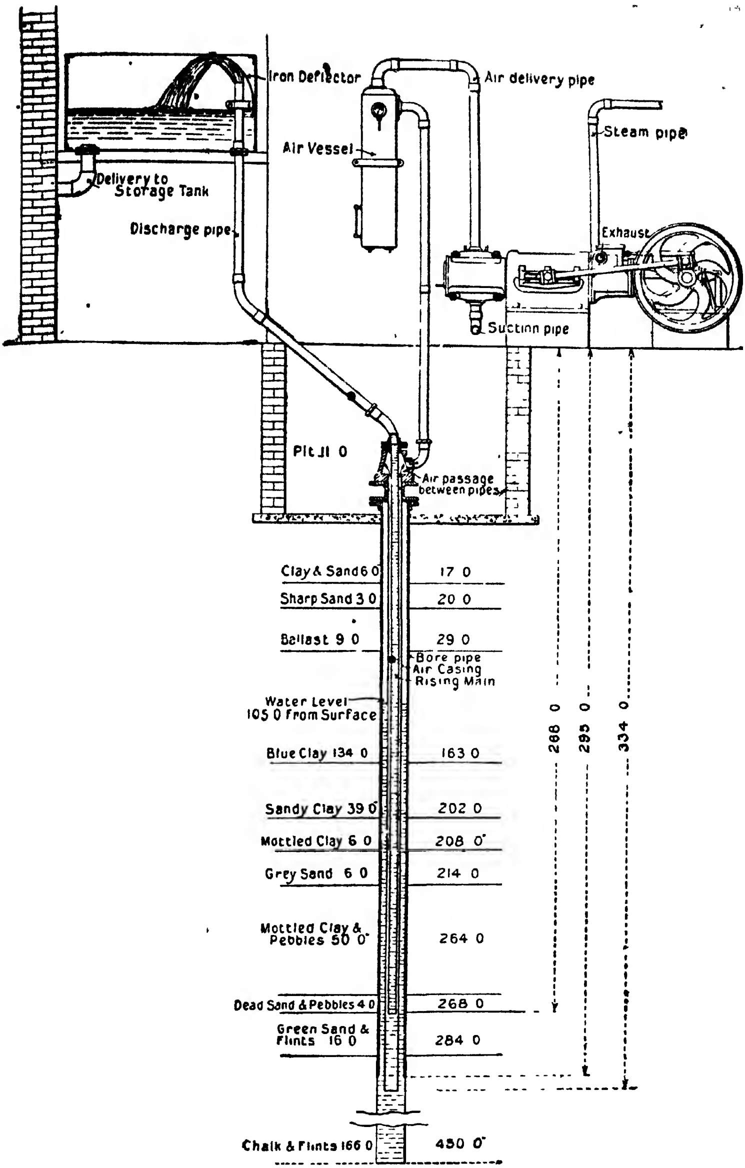


FIG. 90.—INSTALLATION OF THE AIR-LIFT SYSTEM,

driven tightly 11 ft. into the chalk. When the well was first sunk the water-level was found to be 110 ft. from the ground; but as soon as pumping commenced it rose 5 ft., and stood at 105 ft., at which level it has since remained. Even when pumping at the rate of 8000 gal. per hour is being carried on, the water-level is unaffected.

The arrangement is shown in Fig. 90 By means of a compressor—actuated by steam in this instance, but just as easily driven by gas or oil engine or an electric motor—air is forced into a receiver, and then conveyed to an annular space between an inner 3-in pipe which forms the rising main for the water, and an outer 5-in. pipe which is still within the lining-tube of the well. The effect of this pressure is to make the water rise in the central pipe, and this continues till the water-level in the outer pipe has descended to the level of the bottom of this tube The air then escapes up this tube, taking the water with it and lifting it to the desired height The size of the central pipe, and the depth to which it must be taken down, are points which have to be carefully arranged to suit each particular case It must be, for instance, of the right diameter, having regard to the quantity of water to be raised; and the amount of submergence found necessary determines the air pressure required. If this pipe is too small, the quantity of water lifted will fall off; if too large, air will be lost. It must also be put down to a certain depth below the level to which the water falls when pumping is going on.

The machinery used consists of a horizontal air-compressor, having a diameter of 10 in. and a stroke of 12 in. With a steam pressure of 60 lb., and when running at 90 revolutions, this compressor is capable of delivering air into the 5-in. tube at a pressure of 70 lb. per square

inch, and of raising 7600 gal. an hour to a height of some 120 ft. At Hyde Park Court the water is first delivered into a receiving tank, whence it flows by gravitation into a further tank situated in another part of the building. When pumping first begins the water is ejected with some force from the rising main, which is hence surrounded by

FIG. 91 —AIR-COMPRESSOR FIXED IN ENGINE-ROOM.

a baffle. Very shortly, however, the violence of the discharge abates, and though slight pulsations are noticed, the delivery is practically continuous and regular.

A view of the compressor as fixed in the engine-room is given in Fig. 91, and another of the flow from the outlet of the "lift" in Fig. 92.

Whenever the conditions are suitable the air-lift pump is a very valuable arrangement for pumping from a bore-hole, and is not limited to this, but is equally useful for a dug well or a sump or other situation, the only essential condi-

FIG 92 —FLOW FROM "LIFT."

tion being sufficient depth of water to submerge the air and delivery pipe for about half their total length or rather more according to the lift. Thus, in the case of a bore-hole in which the pumping level stood at 100 feet from the

surface the pipes should be submerged about 120 feet below the level, making a total length of 220 feet of pipe, and if the water is required to be delivered above surface a corresponding length of pipe must be submerged. This depth of water required to work in is the only limitation of the system, although it is not recommended for more than about 250 feet total lift; this, however, is an ample lift for most borings for water-supply, and in the greatest number of cases the depth of water is sufficient. On low lifts of only about 40 feet or so a less proportion of submergence is sufficient, but on a greater lift than this, although the pump will work with much less submergence than mentioned, it is only at the cost of pumping an excessive quantity of air, and so spoiling the economy. On the other hand, if the submergence employed is greatly in excess, although a less volume of air is necessary, the increased pressure at which it has to be delivered to overcome the head of water above the end of the pipe, causes a greater loss of power than is compensated for by the less volume of air delivered, and the result is again a loss of economy.

The system claims several advantages over all others, and perhaps the chief of these is that there are no valves or any moving parts below surface, the whole arrangement consisting of straight open-ended pipes which cannot by any possibility go wrong or require taking out, the only machinery being the air-compressor which is on the surface and readily accessible Another point is, that even if a considerable quantity of sand comes in with the water it will not clog the pump, which will easily throw large quantities of sand or mud with the water without being injured in the least. Also, it is the only system whereby duplicate pumping machinery can be applied to a single bore-hole, a second air-compressor being all that

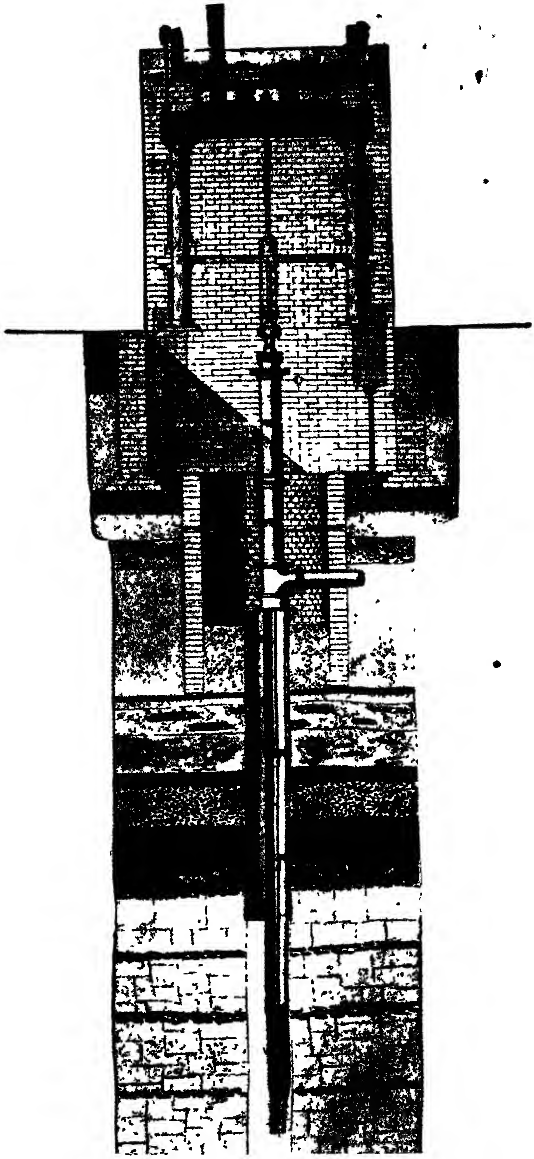


FIG. 93.—DEEP-WELL PUMP PARTLY FIXED IN AN EXISTING DUG WELL.

is necessary, thus saving the expense of a duplicate bore-hole.

Another very useful application of this system is for temporary test-pumping plants, where it is valuable on account of the ease with which it can be fixed, the self-contained compressor being very simple to put down compared to the heavy gear and engine required for an ordinary deep-well pump.

Another important point is, that it enables larger volumes of water to be lifted from smaller bore-holes than can possibly be lifted by any other kind of pump Whatever the bore-hole yields it can be obtained by the air-lift pump For oil wells it should prove indispensable and of the greatest economy and reliance, also for mining purposes.

The cost of pumping at Hyde Park Court is about 1½*d.* per 1000 gallons, as against 4*d.* to 6*d.* per 1000 gallons charged by water companies, in addition to which the supply is *certain at all seasons* and *absolutely pure and cool.*

It will be readily seen that no difficulties are experienced in raising small or large supplies from any depth. It should be borne in mind that one of the most important points to study is the proper submergence of the pump-barrel. It should never be less than 50 ft., and if 100 ft. are available, by all means fix it at the deeper level. Taking this step ensures obtaining a continuous supply, and one not likely to be affected by drought or neighbouring wells. In most instances the head of water is also likely to be lowered a few feet beyond original level by pumping. Taking the above precaution prevents the pump being in any way affected. See following illustrations.

Fig. 93 illustrates an improved deep-well pump fixed

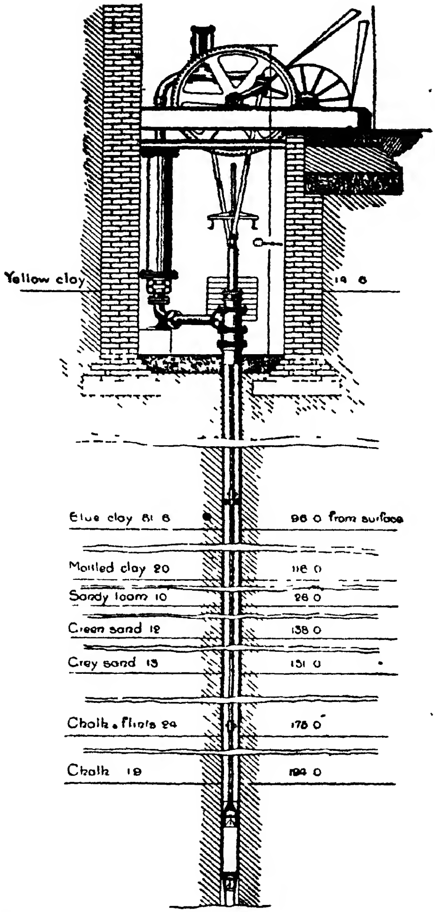


FIG. 94.—IMPROVED DEEP-WELL PUMP FIXED IN BORE-HOLE.

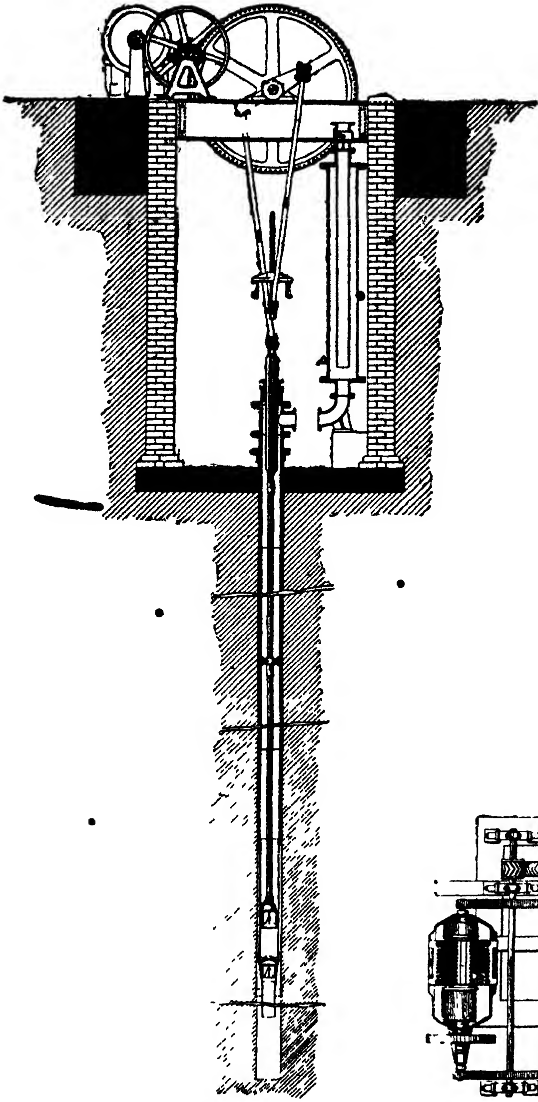


FIG. 95.

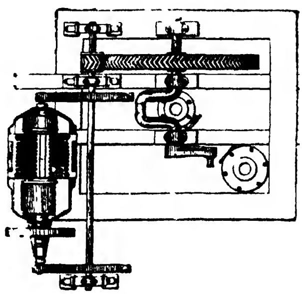


FIG. 96.

in an existing dug well, 400 ft. deep, at Barclay, Perkins & Co.'s Brewery, Southwark, London. The pump reaches 300 ft. from the surface.

Fig. 94 shows a similar pump, at 233½ ft. from surface, in the Idris Co.'s well.

A representation of the author's improved deep well pumps connected to an electric motor is given in Figs. 95 and 96, which represent an artesian bored tube-well, fixed at Showell's Brewery, Langley, near Birmingham. The depth of the bore hole is 600 ft. The pump reaches the depth of 330 ft. from the surface

In Fig 97 is an improved deep-well pump for heavy lifts, which can be driven by any power. It represents a bore hole 400 ft deep, 20 in. diam., with a 16-in. deep-well pump, raising 25,000 gal. per hour, at the pumping station of the East Worcestershire Water-works, Burcot, near Bromsgrove.

A section of the author's improved deep-well pump barrel, with bucket, valve, etc, is seen in Fig. 98. The pump barrels are made of a tough yellow metal, solid drawn, which ensures a sound article and not liable to have blowholes, as is often the case with a cast pump barrel. It will be observed that no loose parts exist in the bucket and valve.

Fig. 99 shows a section of an improved deep-well pump and gearing fitted with fast and loose pulleys, and counter-balance arrangement. The plunger, fitted in the stuffing box at the outlet, enables an unfluctuating yield to be obtained.

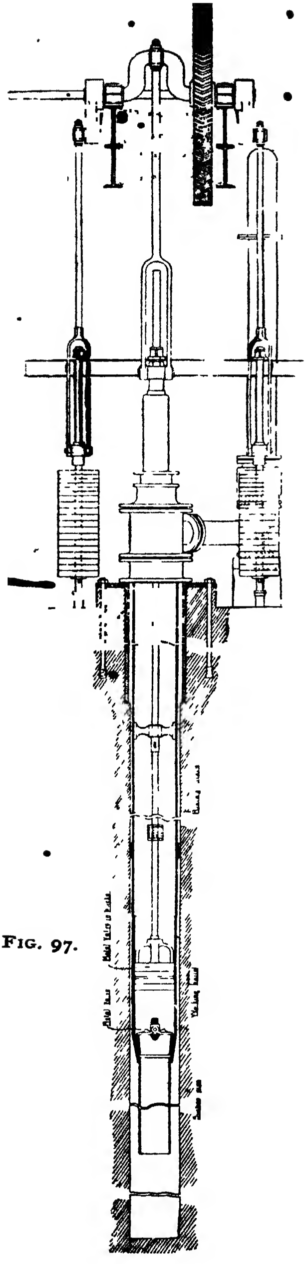


FIG. 97.

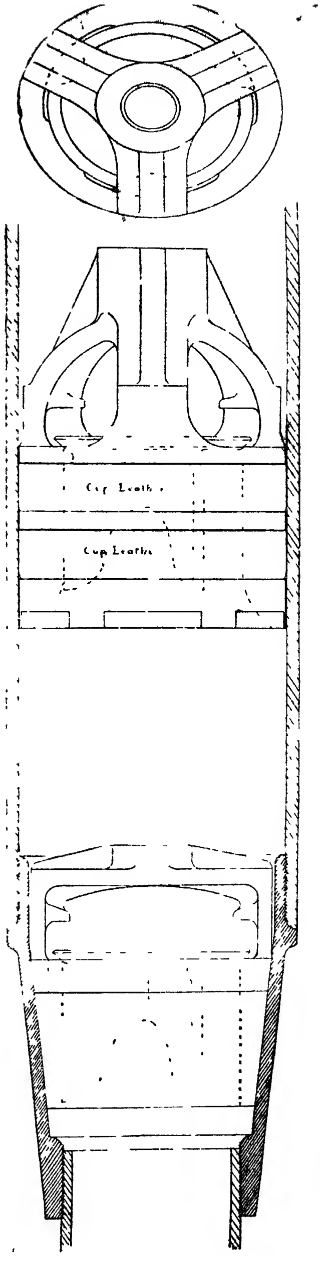


FIG. 98.

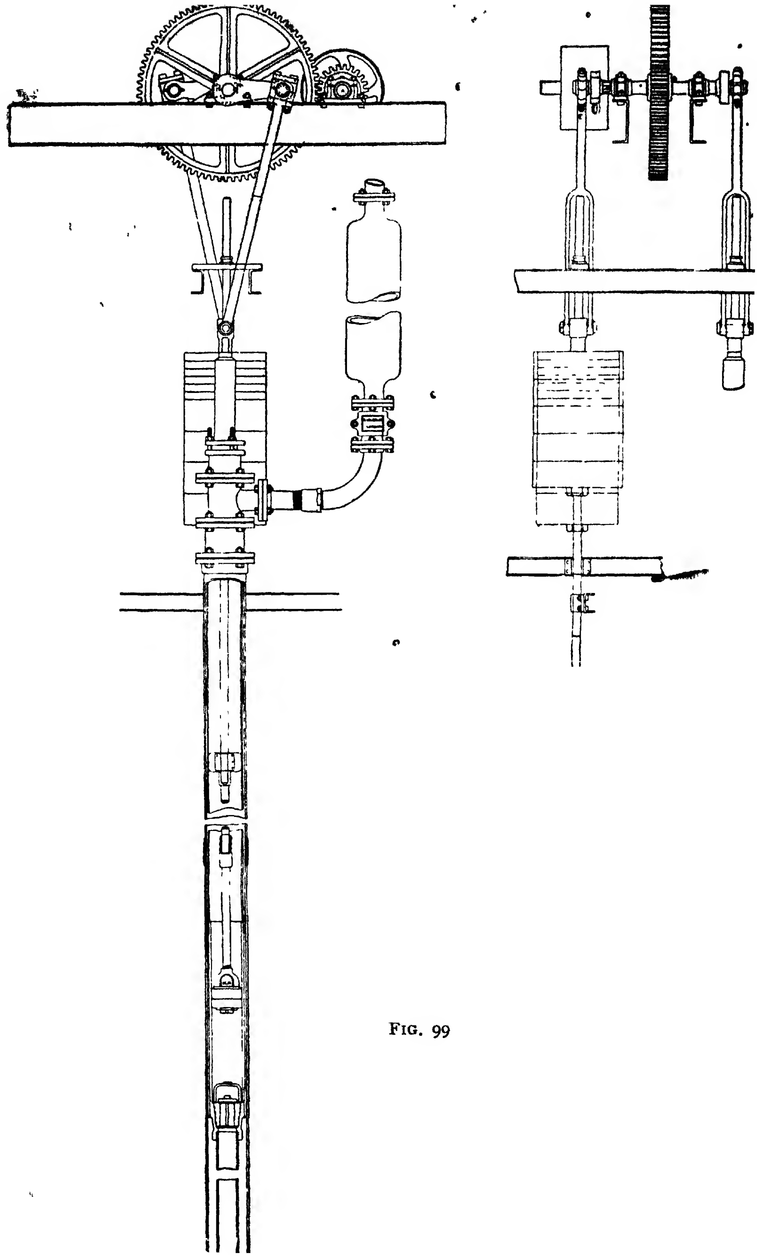


FIG. 99

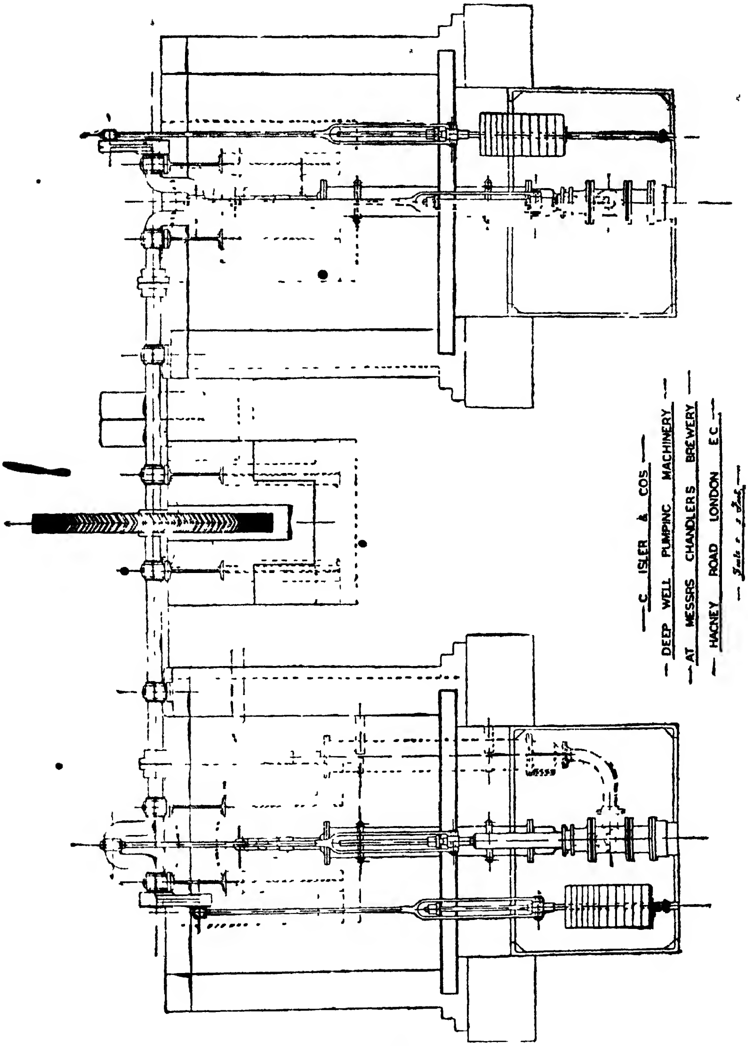

C ISLER & COS
DEEP WELL PUMPING MACHINERY
AT MESSRS CHANDLERS BREWERY
HACKNEY ROAD LONDON E C

FIG. 100.

Fig. 100 illustrates an improved arrangement showing how large supplies of water can be obtained by coupling two or more wells together, although the water level may be much below 30 ft. from the surface. The deep-well pumps are placed in position and connected; when coupled, there is no occasion to utilise the counterbalance weight,

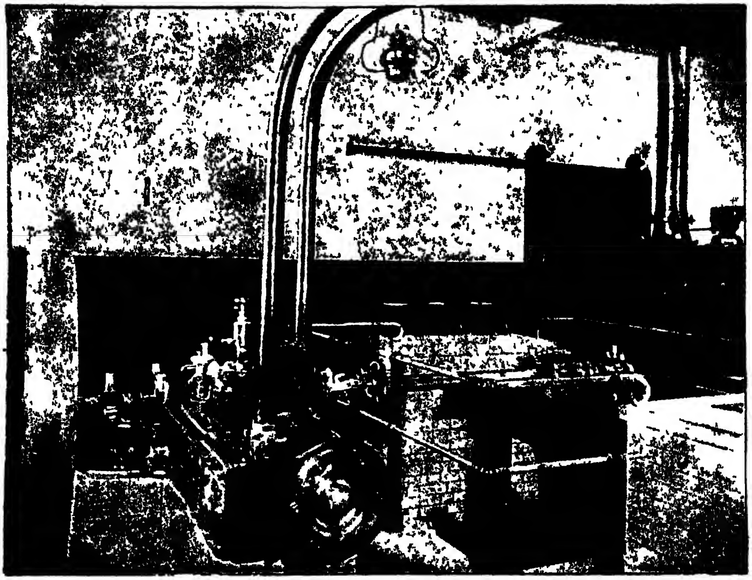


FIG. 101

as one pump works against the other, equalising the load. The counterbalance arrangement is employed when only one pump is required to work.

Fig. 101 represents the engine-room, deep-well pump gear, etc., fixed to supply the town of Hatfield. It is an 1887 Jubilee gift of the Marquis of Salisbury. The con-

sumption having since considerably increased, another installation of treble the capacity has been put down. Each bore hole is 300 ft deep, with a deep-well pump fixed in each. The yield of two is at present over 10,000 gal. per hour.

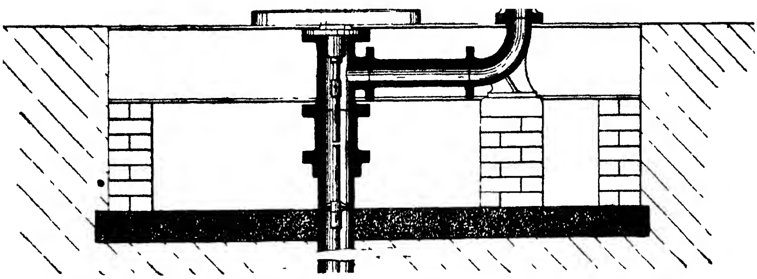


FIG 102

Fig. 102 illustrates a type of steam cylinder most adaptable where the space available is limited. It dispenses with gearing and is expeditiously fixed, and can be bolted to timbers.

STANDARD SIZES OF TUBES AND PUMPS IN INCHES.

Bore pipes . . .	3	4	5	6	7¼	8½	10	11½	13½	15½	18	20
Pump mains . .	2	3	4	5	6	7¼	8½	10	11½	13½	15½	18
Pump barrels .	1¾	2¾	3¾	4¼	5¾	6¾	8	9½	11	13	15	16

TABLES OF YIELD OF DEEP-WELL PUMPS

Size of barrel . .	1¾"				2¾"			
Length of stroke . .	9"		1' 3"		9"			
Number of revolutions per minute	18	22	18	22	18	22	18	22
Gallons per hour .	80	96	131	160	194	240	328	400

Size of barrel . .	3¾"				4¼"			
Length of stroke	9"		1' 3"		1' 6"		2' 0"	
Number of revolutions per minute . .	18	22	18	22	16	20	16	
Gallons per hour .	366	447	595	741	1044	1305	1368	1710

Size of barrel .	5¾"				6¾"			
Length of stroke . .	2' 0"		2' 6"		2' 6"		3' 0"	
Number of revolutions per minute . .	16	20	16	20	14	18	14	
Gallons per hour . .	2043	2554	2554	3211	2993	3848	3691	

Size of barrel .	8"				9½"			
Length of stroke . .	2' 6"		3' 0"		3' 0"		3' 6"	
Number of revolutions per minute . .	14	18	14	18	14	18	14	18
Gallons per hour .	4323	5558	5175	6679	7326	9419	8547	10,988

TABLES OF YIELD OF DEEP-WELL PUMPS—*continued.*

Size of barrel	11″				13″			
Length of stroke	3′ 0″		3′ 6″		3′ 0″		3′ 6″	
Number of revolutions per minute	14	18	14	18	13	17	13	17
Gallons per hour	9816	12,624	11,452	14,724	12,738	16,657	14,820	19,380
Size of barrel	15″				16″			
Length of stroke	3′ 0″		3′ 6″		3′ 6″		4′ 0″	
Number of revolutions per minute	13	17	13	17	12	16	12	16
Gallons per hour	16,964	22,180	19,783	25,873	20,726	27,634	23,735	31,647

REMARKABLE OVERFLOW FROM THE LOWER GREENSAND FORMATION AT SLOUGH, BUCKS.

We have recently completed an Artesian bored tube well to the depth of 1035 feet at the factory of Messrs. Horlick's Malted Food, Limited, at Slough, Bucks This

FIG. 103

boring has been carried through the Clay and Sand Beds overlying the Chalk, through the Chalk and Gault, into the Lower Greensand Formation. Immediately the latter stratum was penetrated, the water commenced to overflow

at the surface, as shown in the previous illustration, at the rate of about 25,000 gallons per hour, which has increased to over 100,000 gallons per hour, after a few days overflow, at 45 lb. per square inch at the surface.

The most important point in connection with this bore-hole is that it is of its kind unique, as it is the first bore-hole carried down into the Lower Greensand Formation which has been successful in tapping a supply of water in London or its vicinity.

FIG 104.

Four bore-holes at least have previously been carried down to great depths in the London Basin, in an attempt to tap the water in the Lower Greensand, but have failed.

These are well known, viz. :—

	Depth.
Tottenham Court Road . . .	1114 ft.
Crossness, Southern Outfall Works .	1060 ft.
Richmond Waterworks . .	1447 ft.
Kentish Town Waterworks . .	1302 ft

The water obtained from this bore-hole at Slough is of great purity and extremely soft, viz. about 6 degrees of

Fig 105.

hardness, and the remarkable results obtained should be of the greatest possible benefit to the country around, and also to large consumers of water.

The Lower Green Sands must not be confused with the Green Sands which are found above the Chalk and form a

part of the Woolwich and Reading Beds. These sands are indeed green in colour, but the "Lower Green Sand" is composed of sand and rocks, often times of a totally different colour to its definition, viz. "Green."

Since the work has been completed we learn that an overflow has also been tapped at Beckton in the same formation. This is all the more interesting and remarkable, as according to data published this formation does not exist at Crossness, and no water was found.

Finding a supply of pure water at Beckton will now induce many firms in that district to venture, as it will enable them to get a water fit for all purposes.

We are prepared to inspect free of charge and furnish estimates.

PARTICULARS OF WELLS.

Name of Place	County	Locality	Depth					Remarks
			Of Shaft	Of Bore	In Tertiary Strata	In Chalk	To Water from Surface	
			feet	feet	feet	feet	feet	
Abingdon	Berks	Council Sheep Market	18	39	39	..	overflows	Water overflows
,, ...	,,	Morland & Sons	.	63	63	..	overflows	,, ,,
,, ...	,,	Winship, Esq, Cothill House	..	138	138	.	.	..
Burnham Grove ..	,,	Rev. Canon Roberts	62	54	62	54	61	Supply 780 gallons per hour
Denchworth	,,	Walker, Esq.		149	149	.		,, 600 ,, ,,
Faringdon	,,	District Council	50	40	90		31	
Hungerford	,,	Eddington House ..	132	100	132	100	128	,, 340 ,, ,,
,, ...	,,	Chess River Trout Farm	..	250	16	234	2	,, 25,000 ,, ,,
Maidenhead	,,	East Berks Brewery	26	102	26	102	18½	Yield 5,000 ,, ,,
Newbury	,,	Mrs. Blythe, Tentfield		180	149	31	42	,, 600 ,, ,,
,, ...	,,	Sandleford Priory .		302	217	85	100	,, 500 ,, ,,
Reading	,,	Messrs Simmonds, H. and G.	..	120	25	95	5	,, 3,240 ,, ,,
,, ...	,,	,, ,,	4	146	28	122	5	,, 1,000 ,, ,,
,, ...	,,	,, ,,	5	337	25	317	5	..
Pinkneys	,,	Ridge Tile Works ..		170	5	165	..	..
Remenham	,,	Park Place	246	234	246	234		..
Streatley	,,	O. Parsons		186′9″	9	177′9″	86	Supply 1,000 gallons per hour
Twyford	,,	Garth, Esq., Haines Hall	36	184	110½	109½	38	,, 770 ,, ,,
Wallingford	,,	E. Wells, Esq., Brewery	6	49	55	..	8	,, 2,160 ,, ,,
,, ...	,,	H. W. Field & Sons, Shillingford, Bry	4	370′6″	374½	..	overflows	,, 420 ,, ,,
,, ...	,,	Lawson, Esq., Ewelme Down	..	449	.	449	290	,, 700 ,, ,,
Wantage	,,	Wantage Brewery Co.	46	404	450	.	83	,, abundant
Windsor	,,	Burge & Co. ..	6	294	89	211	21	,, 3.000 ,, ,,

Windsor	Berks	R White & Sons	3	354'8"	195	162'8"	9	Supply 1,000 gallons per hour
,, (Old)	,,	The Union	60	370	267	163	50	,, 1,000 ,, ,,
,, ,,	,,	Lock		153	138	15	35	Trial boring
,, ,,	,,	From Mr Powhell's (notebook)		204	204			Sand touched at 204 ft
,,	,,	Castle (in Round Tower)	60			110½	160½	Level of Thames
,, Park	,,	The Conservatory Cottage		396	396		240	Sand touched at 370 ft.
Winkfield Row	,,	(Capt Forbes) ?		270	270			All blue clay
Birmingham	Warwick	Alldays and Onions	90	746			87	Supply 8,000 gallons per hour
,,	,,	Allen Everitt & Sons, Smethwick	12	288			54	Supply minimum 6,000 gallons per hour In conglomerate, 8 ft 6 in
,,	,,	Birmingham Carbonic Acid Co, Ltd, Saltley Bridge		251'6"			19	Supply 8,000 gallons per hour
,,	,,	Birmingham Railway Carriage Works	15	350			82	Supply 6,000 ,, ,,
,,	,,	C A M., W A L	5	215			11	Supply 1,200 ,, ,, In sandstone 165 ft.
,,	,,	Cheshires Brewery, Smethwick	7	203				Supply 6,000 gallons per hour
,,	,,	Clifford's Rolling Mills		250			68	(When pumping 2,650 gallons per hour)
,,	,,	J Cox, Esq, Aston Road	8	167'6"			15	Supply 5,000 gallons per hour Bottom strata, sandstone 8' 6"
,,	,,	Dare & Sons, Brewers		682'6"			62	Supply 5,500 gallons per hour
,,	,,	Elliott's Metal Co, Selly Oak		703 8"			82	,, 9,000 ,, ,, In sand rock, 3 ft. 6 in.
,,	,,	Fardon's Vinegar Brewery, Glover Street	60	269			47	Supply 2,800 gallons per hour
,,	,,	Grand Hotel, No. 1	15	506			71	,, 4,000 ,, ,, In sandstone, 506 ft.
,, ..	,,	,, ,, No 2 ..	15	570			71	Supply 4,000 gallons per hour In sandstone, 570 ft.

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth					Remarks
			Of Shaft	Of Bore	In Tertiary Strata	In Chalk	To Water from Surface	
			feet	feet	feet	feet	feet	
Birmingham	Warwick	Guest, Keen & Nettlefolds, Smethwick		400			20	Supply 18,000 gallons per hour
,,	,,	Gas Works, Duddleston Mill Road	35	352			15	Minimum supply 7,000 gallons per hour
,,	,,	Holt Brewery, Holt St		467			58′ 6″	Supply 16,000 gallons per hour
,,	,,	Hipkins & Co., Ltd, Summer Hill		225				,, 5,000 ,, ,,
,,	,,	Thos Hill, Ltd., Hampton Street		212			74	,, 1,000 ,, ,,
,,	,,	Kenways, Ltd., Moore Street	9	241			50	,, 6,000 ,, ,,
,,	,,	Linde British Refrigerating Co	5	227′ 6″			*overflows 6″ above surface*	,, 12,000 ,, ,,
,,	,,	London & North Western Railway	7	493′ 6″			62	,, 7,600 ,, ,,
,,	,,	Metropolitan Amalgamated Railway Carriage and Wagon Co., Saltley	5	295			11	,, 8,000 ,, ,,
,,	,,	Midland Hotel	14′ 9″	494′ 3″			46	,, 8,000 ,, ,,
,,	,,	The Mint	43	620			46	,, 10 to 20,000 gals. per hr.
,,	,,	Mitchell & Butlers, Smethwick	17	284			96	,, 4,050 gallons ,,
,,	,,	,,	17	284			96	,, 4,050 ,, ,,
,,	,,	,,		558			97	,, 28,000 ,, ,, In marl, 117 ft
,,	,,	Perry & Co., Lancaster Gate	57	243			52	Supply 8,000 ,, ,,

Birmingham	Warwick	Rushton's Brewery, Aston Road		400	..	32' 6"	Supply 10,000 gallons per hour
,,	,,	Showell's Bottling Stores, Bordesley Street	6	244		9	,, 4,800 ,, ,, Minimum supply
,,	,,	E J Smart & Sons		727		40	Supply 13,000–15,000 gallons per hour In sandstone, 127 ft.
,,	,,	Smith, Stone & Knight, Saltley		260			Supply 3,000 gallons per hour.
,,	,,	Smethwick Gas Works		300	..	65	,, 10,000 ,, ,, Sand rock, with thin layers of clay, 67 ft
,,	,,	Tailby & Co, Ltd Bordesley Street	10	409		8	Supply 1,700 gallons per hour
,,	,,	H H Vivian & Co, Ickdield Port Road		327		70	,, 3,360 ,, ,,
,,	,,	R White & Sons, Saltley	12	245		22	,, 8,000 ,, ,,
,,	,,	R. White & Sons, Winson Green	19	349		83	,, 15,000 ,, ,,
,,	,,	A W Wills & Sons, Nechell Park Road	6	194		16	,, 3,600 ,, ,, In sandstone, 9 ft
,,	,,	J H Woodhouse, Smethwick Laundry	11	190		62' 6"	Supply 1,250 gallons per hour
,,	,,	The Workhouse, Western Road	8	492		94	,, 8,000 ,, ,,
,,	,,	Samuel White, Esq., Winson Green	10	290		95	,, 1,680 ,, ,,
,,	,,	Watson, Todd & Co, Midland Flour Mills	75	325		45	,, 18,000 ,, ,,
Bloxwich	Staffs	Bloxwich Brewery Co	155	99		145	Supply 3,000 gallons per hour
Bromsgrove	Worc	East Worcester Waterworks	19	381		85	,, 30,000 ,, ,, In sandstone, 329 ft. ,, 14 ft
,,	,,	East Worcester, Catshill		300		2' 7"	Supply 20,000 gallons per hour
,,	,,	East Worcester, Catshill	10	297		overflows	,, 20,000 ,, ,, In sandstone, 127 ft

PARTICULARS OF WELLS—*continued*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Coventry	Warwick	Coventry Ordnance Works		352			12' 6"	Supply 10,000 gallons per hour Sand rock, 19 ft.
,,	,,	A Kirby, Esq		150				Supply 400 gallons per hour
,,	,,	L & N W Railway	78	194			52	,, 9,000 ,, ,, In sandstone and clay 1 ft. 6 in.
,,	,,	Phillips & Marriott, Brewers	53	168' 6"				In sand rock, 7 ft. 6 in. Supply 5,000 gallons per hour
,,	,,	W Ratcliffe, Esq	6	144' 9"			48	,, 360 ,, ,,
,,	,,	Coventry Electric Tramways	6	366				,, 8,000 ,, ,,
,,	,,	Messrs Courtauld	85	617			14	,, 19,000 ,, ,, In sandstone, 13 ft
,,	,,	Messrs Humbers		250				Supply 4,000 gallons per hour
,,	,,	,, ,, Folly Lane		520				,, 5,800 ,, ,,
Oldbury	Worc	Showells, Ltd, Langley	11' 6"	586' 3"			38	,, 6,000 ,, ,, In marl, 27 ft. 3 in.
Rednal	Shrops	Great Western Railway		925			2' 6"	Supply 6,276 gallons per hour
Shenstone	Staffs	South Staffs Waterworks		216			9	,, 22,800 ,, ,, In marl 13 ft.
Stourbridge	Worc	North Worcestershire Brewery Company	39	216			41	Supply 8,000 gallons per hour In sandstone and marl, 5 ft.
,,	,,	Baths	10	245			26	Supply 5,400 gallons per hour In sandstone. 245 feet
,,	,,	Gasworks, Turney St.	24	191			23	Supply 6000 gallons per hour In hard sandstone, 191 ft
,,	,,	Waterworks	10	190			27	Supply 20,000 gallons per hour In hard sandstone, 140 ft 6 in.

Walsall	Staffs.	A Smith & Sons	18	99			.	Supply 500 gallons per hour In limestone, 76 ft.
,,	,,	Walsall Gasworks	15	460′ 6″			12	Supply 3,540 gallons per hour In fire-clay rock, 10 ft. 6 in.
,,	,,	Showells, Ltd., Corporation Street	54	48′ 6″			18	In limestone, 3 ft.
,,	,,	Showells, Station St.	44′ 6″	54				,, ,, 54 ft.
West Bromwich	,,	H. Bates, Esq., Spur Lane	8	349			5	Supply 3,000 gallons per hour
,,	,,	A J. Price, Esq., Lewisham Brewery	14	384			76	,, 3,000 ,, ,, In marl and sandstone 45 ft
,,	,,	Alfred Powell & Sons	61	139			54	Yield 720 gallons per hour In sandstone 21 ft.
Wolverhampton	,,	C H Chater & Co, Limited, Brewers, Market Street	12	150			61′ 6″	Supply 2,400 gallons per hour In sandstone 29 ft.
,,	,,	New Union	10	300′ 6″			15	In marl rock 2 ft. 6 in.
,,	,,	F Russell, Esq, Great Western Street	40	290			36	Supply 1,500 gallons per hour In red sandstone rock, 8 ft
,,	,,	South Staffs Brewery Co	64	194			62	Supply 3,500 to 4,000 gallons per hour In red sandstone. 1 ft
,,	,,	Wolverhampton Corporation, Dimmingsdale	5	295			26	Supply 42,000 gallons per hour Bottom soil red sandstone 295 ft
,,	,,	Wolverhampton & Dudley, Brewers	90	168			75	Supply 5,000 gallons per hour
,,	,,	F Myatt, Esq, Brewer		280			66′ 3″	,, 5,000 ,, ,, In hard red sandstone, 202 ft.
,,	,,	L. & N W Railway, Bushbury		272				Supply 17,800 gallons per hour
,,	,,	Great Western Railway, near Shifnal		250	.	.	..	,, 25,000 ,, ,,
,,	,,	Great Western Railway		787	.		16	Supply about 63,000 gallons per hour Into conglomerate, 21 ft. 3 in

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth: Of Shaft	Of Bore	In Tertiary Strata	In Chalk	To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Amersham	Bucks	Raans Farm (*for Lord Chesham*)	186	222	20	388		.
,, ..	,,	Weller's Brewery	12	99	24	87	9	Supply 4,300 gallons per hour
,,	,,	Water Co	6	144	15	135	5	,, 15,000 ,, ,,
,, ..	,,	G Darlington, Esq.	18	43	47½	13' 6"	50	.
Burnham .	,,	Brown and Terry	78	51	78	51	89	,, 1,000 ,, ,,
,, .. .	,,	Waterworks ..	102	150	80	172	89	,, 8,000 ,, ,, This borehole was deepened to 350 ft. in 1909
,, ..	,,	,,		300	72	228	95	Supply 8,844 gallons per hour
Buckingham	,,	District Council		300	300		124' 6"	
Chesham ..	,,	Waterworks	5	230	7	228		..
Denham . .	,,	Pauling & Co. Ltd	6' 6"	45	29½	22		5 in trial hole to find depth of chalk, which is 29 ft. 6 in.
Ditton Park .	,,	Between Slough and Colnbrook		450	70	380		Water overflows into tank 19 ft above surface
Fulmer .. .	,,	Public well, close to Church	17	158	69	105		..
High Wycombe ..	,,	Waterworks	6	165	4½	166½		..
Iver	,,	R Taylor, Esq, Huntsmoor Park	10	194	126	78		Water overflows supply —900 gallons per hour
Linslade	,,	Waterworks ..	.	150	150		62	Supply 10,000 gallons per hour
Princes Risborough	,,	J Forrest, Esq .		99' 6"	20	79' 6'		
,, ,,	,,	Phillips, Esq	126	144	270		118' 2"	,, 1,000 ,, ,,
Slough .. .	,,	Horlicks Milk Factory		1037		right through chalk	overflowing	18 inches into lower green sands Supply 100,000 gallons per hour, overflowing

Slough	Bucks	Railway Station .		47	47	..	.	This well must have been sunk where the brick earth had been worked from off the gravel, and must go through the London clay
Snackley .	,,	T B Ford, Esq, Paper Mills	15	290	26½	278′ 6″	19	Supply 20,000 gallons per hour
Stoke Poges	,,	Mr Polwheles Note-book		72	72	..	..	The London clay is most likely sunk through at this depth
The Thorn ..	,,	Nr Great Berkhampstead, between Chesham and Berkhampstead	180	130	40	270		
Wendover	,,	Sir J. L Walton, K C, M P		243			.	Yield 6,000 gallons per hour
,,	,,	Sir Thomas Barlow	160	50		all chalk	159	,, 1,000 ,,
Woburn cr Hendsol	,,	Bourne End		380	380			
Wraysbury	,,	A H Benson, Esq		270	169	101	20′ 6″	,, 2,000 ,, ,,
High Wycombe	,,	Sanders & Co	6	94	23	77	13	Supply 5,000 ,, ,,
Abridge	Essex	Hargreaves Brewery		436	326	110	37	Supply 2,000 gallons per hour
Althorn .	,,	Railway Station	16	330	346		21	Water rose to within 21 ft of new surface at the rate of 2 gallons per minute
Aveley Marsh	,,	Marshfoot Farm		107	70	37		Water rose to surface, yield 15 gallons per minute
Barking	,,	Barking Mills .		396	161	235	16	Yield about 30 gallons per min
,,	,,	Mission Hall .	72	316¼	243½	145	66	
,, .	,,	Whites' Mineral Water Works	10	573	182½	400½	24½	
,, .	,,	R. White & Sons, Ltd.		91′ 10″	91′ 10″		37′ 6″	Supply 1,000 gallons per hour
Bishops Stortford	,,	Bailey Bros		250	94	156	77	,, 5,000 ,, ,,
Billericay .	,,	Waterworks ..		900	499′ 6″	400′ 6″		,, 4,600 ,, ,,
Brentwood	,,	Essex Lunatic Asylum	410′ 4″	298′ 8″	553½	155½	209	

PARTICULARS OF WELLS—*continued*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Bulphan Fen	Essex	At the edge of uplands		110	68	42	1	Supply about 30,000 gallons per day
Canewdon	,,	Pudsey Hall		297	297			Ending in (London) blue clay Water abundant and good
Canvey Island	,,	Eldon Engineering Co.	6	316	322			
,, ,,	,,	Harrison, Esq, Waterside Farm		492	466½	25′ 6″	74	Supply 200 gallons per hour
Chadwell Heath	,,	Near 10 mile stone on the road from Romford to London	45	55	100			Good supply of water (Two wells at Romford are reported the same)
,, ,,	,,	Mr Oldakers		196	196		86	Bored throughout
,, ,,	,,	Asylum	12	340	209	143	74	Supply 6,000 gallons per hour
Chelmsford	,,	T. A Cawley	5	62	67			
,,	,,	Ridley's Flour Mills	196	185	339	42	101	,, 10,000 ,, ,,
,,	,,	Wells & Perry		420	346	74	110	,, 6,000 ,, ,,
Chigwell	,,	Grange Hill	228	170	398		160	Water abundant
Chingford Mill	,,	East London Waterworks Co	50	401	111½	309½		Water rose from the bore to 5 ft 1 in above surface Water level in July 1885, 2 to 3 in below surface
Claybury	,,	Claybury Asylum	16	499	406	109	226	
Coggeshall	,,	J K King, Esq, Brewery		305	226	79	overflows	Yield 4,000 gallons per hour
Colchester	,,	Cuddon & Sons	8	228	185	51	50	,, very plentiful
,,	,,	New County Asylum		523	245	278	143	,, 8,000 gallons per hour
Cold Norton	,,	Purleigh Ry. Station	16	375⅔	391⅔		86	
Corringham	,,	Tilbury Brickfields Co	180	792′ 4″	506	466⅓		
Dagenham Hall	,,	Sir T. Neaves		404	404		200	To sand about 404 ft. Good supply

Dunton . .	Essex	Mr. Willoughby's	100	344	444	.	77	(10 in. "water rock" 354 ft.) Water contains sulphate of magnesia
East Donyland	,,	Waterworks	.	140	104	36	9	Supply 7,600 gallons per hour
Eastwood	,,	J Wagstaff, Esq ..	14	519	533	.	255	,, 600 ,, ,,
,, .	,,	G. Scott Miller, Esq.	178	475	451	202	224	,, 630 ,, ,, Water level in dug well, 91 ft.
Epping .	,,	Conybeare & Phillips	200	220	420		26	
Fambridge Ferry	,,	3 miles N. of Rockford	.	362	362			Water rock 2 ft, reached at 360 ft
Foulness Island	,,	B C Hall, Esq		561	502	59		Supply 720 gallons per hour
Foxearth .	,,	Ward & Sons	6	120	62	64	45	,, 1,200 ,, ,,
,,	,,	,, ,,	6	262' 6"	51' 6"	217	46	,, 1,200 ,, ,,
Grays	,,	Messrs Brooks, Shoolbridge & Co	10	130	24	116	12	,, 9,000 ,, ,,
,, ..	,,	Exmouth Training Ship		100	60	40	16	. 1,800 ,, ,,
,, .	,,	Hilton, Anderson & Brooks	50	100	50	100	15	,, 1,000 ,, ,, All boring through chalk
,, .	,,	Orsett Union	35	165	124	76	28	Supply 6,000 gallons per hour
,,	,,	Seabrooke & Son		400	258	142	3	,, abundant
,, .. .	,,	,, ,,		400	250¼	149' 9"		,,
,,	,,	,, ,,	.	63		63	19	,, ,,
,, .	,,	,, ,,	.	500		500	17	Yield ,,
Hackley	,,	A C W Hobman & Co		370	370		75	,, 1,200 gallons per hour
Havering .	,,	Mr. Bray's .		533	533			
,,	,,	Pyrgo Park	273		136¼	136½	270	, 700 ,, ,,
Halstead	,,	C F. Shoolbred, Esq		400	256	144	122	,, 1,200 ,, ,,
Ilford .	,,	Britannia Works	27	265	163½	128½	23	
,,	,,	Broadway	63	53	116		30	
,, .	,,	Downhall Farm		208	152	55	27	
,, ..	,,	Near row of houses, opposite Red House	87	214	301	..	52	Abundant supply
Ingatestone	,,	Parry, Esq .	22	429	451		122	
Kelvedon .	,,	J Fuller, Esq, Brewery	8	370	268	110	4	300 gallons per hour
,,	,,	Thorn & Livermore .	6	596	408	194	154	
Kynochtown	,,	Kynock, Ltd.		73' 6"	73' 6"	.		
,, ..	,,	,, ,,	..	61' 6"	61' 6"	.	6	
Laindon . ..	,,	Railway Station	.	788	483	305	122	

PARTICULARS OF WELLS—*continued*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Langford	Essex	Longford, nr Maldon		150	150	.	5 ft above surface	Through clay (London) to fine sand with shells Water rose 5 ft above surface
Latchingdon	,,	Tyle Hall		475	475		168	..
Leytonstone	,,	West Ham Union		165	110	55 ?		
Loughton	,,	G E R Station	101	854	955		64	
Maldon	,,	Gray & Sons	152	115	267		124	
,,	,,	Warren's Foundry (*nr Railway Station*)		130	130			Through gravel and London clay (*To sand*, 151 ft)
,,	,,	Bentall's Nut and Bolt Factory	75	51	126			Maiden spring 90 ft. down
,,	,,	Mr Bentall's House, about 100 yards from the above		126	126			To sand and water
Mucking	,,	Mucking Ford		67	51	16		Water rose to 14 ft above surface at the rate of 90 gals. per min., which has increased to 110 gals. per min
Nashing Park	,,		sunk 194	34	228			
North Fambridge	,,	Railway Station	15	346	361		13½	Yield at 28 ft. down, 5 gallons per minute
Plaistow Wharf	,,	Lyle & Co		635	151	484		
Poplar	,,	Workhouse		350	137	213	49	
Potter Street	,,	Whitehouse		178	178			
Prittlewell	,,	For the Southend Waterworks	360	506′ 7″	561′ 7″	305	143	
Purfleet	,,	St Louis Park Mills		252	50	202		
,,	,,	Tank Storage Co	..	100	50	50	3	Supply 700 gallons per hour

Rainham	Essex	City Corporation		57' 6"				Trial hole
"	"	Field's Candle Works		350	181	169	4	Yield 3,000 gallons per hour
"	"	Salamon & Co		406	216' 6"	189' 6"	9	" 4,000 " "
"	"	Wickens Pease & Co		346	225	121		" 3,000 " "
Rayleigh	"	Pinkerton, Esq		551' 6"	551' 6"		90–100	Chalk touched at 551 ft 6 in.
Rettenden	"	Battle Bridge		423	423		64½	
"	"	Battle Bridge Railway Station	32	333	365			Water rose to within 24 ft. of surface, at the rate of 5 gals. per min
Roydon	"	J A Maunder, Esq., Briggin's Park	9	349	172	186	32	Supply 4,200 gallons per hour
Rochford	"	The Union		230	230			
Rushley	"	An Island near Rochford		485¾	485¾		over 50 water overflowed	..
Sewardstone	"	South of Waltham Abbey						To the bottom of the London clay, 122 ft
Southchurch	"			395	395		36	
Southend	"	On the Green, Lower Southend		475	475			To sand and water, 475 ft
"	"	Railway Station		395	395			
Stanford-le-Hope	"	Kynock, Limited		97' 6"	97' 6"			
" "	"	Sculling Bros	40	29	29		36	Supply 360 gallons per hour
Stratford	"	Messrs Howard & Sons Chemical Works	14	236	135' 6"	114' 6"	31	
"	"	Phœnix Black Works Abbey Mills		200	132¼	67¾		
Thames Haven	"	Cattle Landing Station		572	268½	303' 6"	overflowed	26,000 gallons a day taken
" "	"	Kynock, Limited	6	91' 6"	97' 6"		6' 6"	Supply, plentiful
" "	"	L. & T. Haven Oil Co		508	180	328	20	" 14,000 gallons per hour
" "	"	L T. & S Railway		572' 3"	268' 8"	303' 7"		" 2,600 " "
" "	"	Seabrooke & Sons		351				" 2,600 " "
Tilbury Fort	"	Old Well	48					(Chalk stones found at a depth of about 80 ft)
" "	"	Newer Well	31	553½	67½	517		
Upminster	"	Rectory	90	60	150			
Vange	"	Brickyard	100	625	524	201	99	
"	"	Public House		100	100			In London clay

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Victoria Docks	Essex	Messrs Duncan Bell & Scott	.					Depth to chalk, 170 ft.
Waltham Abbey	,,	Joyce's Percussion Cap Factory		94	94		.	London clay to green sand
,, ,,	,,	East London Water-works	12	186	123	75		Good supply
Waltham Cross	,,	Colvin, Esq	98	249	200	147	97	
,, ,,	,,	Lady Meux		351′ 6″	172	179′ 6″	115	Supply 4,500 gallons per hour
,, ,,	,,	R White & Sons	5′ 6′	358′ 6″	104	260	15	,, 2,250 ,, ,,
Walthamstow	,,	Clay Street	90	100	190			To chalk 190 ft
,, Marsh	,,	East London Water-works		$134\frac{1}{3}$	$134\frac{1}{3}$			
Warley .	,,	Parsonage	100	280	380			To sand below the blue London clay, reached at 390 ft
West Honningfield	,,	Rectory		461	461			Sand reached and water broke in at 462 ft. Water rose 213 ft in $2\frac{1}{2}$ hours
West Tilbury	,,	New Cottages, north of Railway Station	25	40	49	16	31	
,, ,,	,,			61	61		56	
Wickham	,,	Murphy, Esq	25	180	167	38	102	
Witham	,,	U D Council		286	237	49		Supply 10,000 gallons per hour
Woodham Ferris	,,	Railway Station	15	$306\frac{1}{3}$	$321\frac{1}{3}$		$7\frac{1}{2}$	

Abbots Hill	Herts	Nr Two Waters	135		135			Chalk and flints, 367 ft
Abbot's Langley	,,	Cecil Lodge	200	201½	15	386½	..	
,, ,,	,,	Waterworks		150	18	132	5½	
Aldenham House	,,	1 mile N W of Elstree	155½	234½	145½	244½		
Barnet	,,	Waterworks .	171	289' 5"	167	293½	155	
Bayford	,,	Near the Church						In chalk at 150 ft
Berkhampstead	,,	Waterworks		170	-2	148	3	Supply 40,000 gallons per hour
Boxmoor	,,	L & N W Railway		91	6	85		
Broxbourne ..	,,	Fishing House		70	70			
,, .	,,	New River Co		196	60	136	11	Great quantity of water
Buntingford	,,	H G Maxwell, Esq	4	282	125	161	160	Supply 480 gallons per hour
Bushey ..	,,	Experimental well in Colne Meadows		150	46	104		Chalk, full of water
,, .	,,	Colne Valley Waterworks	95	140		235		All chalk and flints Yield, 1,000,000 gallons in 24 hours
,,	,	Colne Valley Waterworks		200	5	touched at 5 ft	16	
,,	,,	Colne Valley Waterworks, new well	43	657		right through chalk	20	9 ft into gault The flow of water from top of borehole is 555,000 gallons in 24 hours
,, ..	,,	Hartsbourne, Bushey Heath		400	230	170		
, . ..	,,	L & N W Railway		96½	13	83½		
,, .	,,	Old Lodge		166	145	21	140	
Cheshunt	,,			157	109	48	.	
,,	,,	Newgate Street		156	47	109	79	
,, .	,,	New River Co	181½	828¼		through chalk	7 to 8	Over 3,000,000 gallons a day from the chalk. To green sand and gault
Chorley Wood .	,,	Parsonage	164 Shaft throughout		62	102	161	Shaft throughout 164 ft.
,, ,, ..	,,	Lady Russel	6	244	25	225	160	Yield 380 gallons per hour
,, ,, .	,,	E Tabernacle	.	226	12	214	120	,, 300 ,, ,,
Elstree ..	,,	Boreham Wood ..		202	202	.	.	To chalk 202 ft.

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Essenden Place ..	Herts			344	172	172		
Gade Valley ..	,,	Messrs Dickinson's Paper Mills, Apsley Mill	16	205	16	205	8	Supply 260,000 gallons per day
,, ,, ..	,,	Do. Nash Mill		210	6	204	7	,, 467.000 ,, ,,
,, ,, .	,,	Do. Home Park Mill	36	196	9	223	9	,, 473,000 ,, ,,
Gorhambury ..	,,	West of St Albans	120	200	15	305		
Hadham ..	,,	Fordham Hall		100	10	90	22	,, 200 gallons per hour
Hatfield .	,,	Waterworks	12	288	45	255	154	,, plentiful
,, ..	,,	,,	16	288	48	256	156′ 8″	,, ,,
,, ..	,,	Ponsbourne Park	10	181½	191½			To chalk at 191½ ft.
Hitchin ..	,,	F Gosling, Esq	133½	160′10″	294⅓		161′ 10″	Supply 1,000 gallons per hour
Hoddesdon ..	,,	Brewery		94	90	4		.
,, ..	,,	Waterworks	95	115	34?	176		..
Kings Langley	,,	Shendish	120	330		chalk	.	..
Langley ..	,,	L & N W Ry.		91	9	82		..
London Colney	,,	All Saints Convent		201				Yield 3,120 gallons per hour
Oxhey ..	,,	S of Watford	126	160	60	226		..
Radlett Station	,,	Midland Railway	60	190	15	235		..
Rickmansworth	,,	Vicarage, Mill End	5	29	15	19		There are two other wells close by, both giving same section
,,	,,	Shepherds Farm, Mill End	5 ft water	28	15	18		..
,,	,,	Batchworth Paper Mills, Messrs Dickinson's	13	319	20	312	7	Supply 502,000 gallons per day
,,	,,	Lond Water Paper Mills		220	15	205		..
,,	,,	Croxley Green, The School		75	8	67	.	Water rose 3 feet

Rickmansworth ..	Herts	Waterworks	26	300	.	through chalk with flints	.	Water rose to 3' 2" above the adjoining river
Royston . .	,,	,, .		280	6	274	154	. ..
,,	,,	,,	12	298	10	300	144	..
,, .	,,	New Printing Works		299	299		4' 6"	Supply 2,000 gallons per hour
St Albans	,,	Wiles & Lewis	140	100	140	100	138	,, 1,600 ,, ,,
Waltham Cross	,,	..		107	107			..
,, ,,	,,	Springsall, near Roman Urn, Cheshunt		142	114	28		..
,, ,, .	,,	Theobald's Square		176	122½	53½	13	.
Watford	,,	Paget Prize Plate Co.	7	113	7	113	43	,, 1,500 ,, ,,
,,	,,	Cannon Brewery ..	25	190	25	190		..
,,	,,	L & N.W. Railway	36	230	12	254		..
,,	,,	,, ,,		195	12	183		..
,,	,,	London Orphan Asylum	51½	255½	51½	255½	52	Yield 80,000 gallons per day
,,	,,	Messrs Sedgwicks & Co.'s New Brewery	5' 2"	227' 10"	10	223		.
,, .	,,	Local Board .. .	8½	142½	25½	125½	11½	Supply 33,000 gallons per hour
,, .	,,	Talpits (Two pits S W. of Town)	15	120	15	120		.
Wormley End .	,,	(Sir A. Home's)			100			Chalk found 100 ft. below surface
Allhallows Marshes	Kent	Near Allhallows Village		250	250		.	Water nearly rose to the top of bore A good supply in Oldhaven beds, 10 ft.
Ash ..	,,	Messrs. Gardner's Brewery		400 or 500	9	394' or 294	65	Supply over 4,000 gallons per hour
Ashford .. .	,,	Ashford Breweries	.	722½	722½	.		The water level stood at 50 ft. at first, and could not be lowered, but it failed after a time from the hole which is only 1½ in diam. at the bottom getting choked. A second boring was therefore made

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Ashford	Kent	Ashford Breweries	95	687	782		54	Supply good
,,	,,	Chapman & Sons	95	339'6"	434'6"			
,,	,,	South Eastern Railway	8	525	533		60	Supply 6,000 gallons per hour
Beckenham	,,	Electric Light Station	.	250	130	120		100 ft above O D
,,	,,	Messrs Pontifex & Hall, Elmer's End Brewery		180	110	70	4 ft above surface	Supply 10,000 gallons a day of ten hours
,,	,,	Messrs Muirhead & Co's Electrical Factory		233	118	115		107 ft above O D
,,	,,	Kent Waterworks, Shortlands	100	150	70	180	8	Supply 5,000,000 gallons a day
,,	,,	Oak Wood House	100	370	201	269	70	
,,	,,	Public Baths		300	129	171		97 ft above O D.
,,	,,	Shortlands (M Wilkinson's)	59	150	109	100	61	Supply 24,000 gals in 24 hours
,,	,,	Victoria Laundry		250	181	69	14	About 178 ft above O D.
Belvidere	,,	Messrs Marshall & Co		250'10"	180	70'10"		Supply 2,000 gallons per hour
,,	,,	Messrs. Price & Co's Mineral Oil Works	41	424		right through chalk	pumped down to 43 ft	11 ft 9 in into rock
,,	,,	Paraffin Works	30	235	141	124		
Benenden	,,	East Benenden		131	131		6	Into Wadhurst clay
Bexley	,,	Messrs Reffell's	6	167	35¼	137¾	2½	Supply good. Pumped for 14 hours (50 barrels an hour)
Bexley Heath	,,	Nr Lord Bexley's Arms		153	135	18		
,, ,,	,,			170	140	30		
,, ,,	,,	Brampton Place		159½	129	30½		

Bexley Heath	Kent	Mr Shelwin's, near the "Lion"	.	140	115	25	.	
,, ,,	,,	Long Lane		214	124	90		
,, ,,	,,	Lamorbey House ..		146	116	30	17	
,, ,,	,,	Nr the Railway Cutting	65	110	129¾	45¾	60	
,, ,,	,,	Sidcup New Homes, Halfway Street		250	128	122	..	
,, ,,	,,	Wansunt Pumping Station, No 1	16	237	11	242		
,, ,,	,,	Ditto, No 2	18	235	11	242		Supply 2,000,000 gallons a day
Birchington	,,	Pettman & Co	6	144	135	15	15	,, 500 gallons per hour
Blackheath	,,	Shooter's Hill Road		139	109	30		
Blean Hill	,,	Westward of Canterbury						To chalk, 160 ft
Bobbing	,	Keycoll Hill, Sittingbourne Waterworks	60	320	120	360	122	About 330,000 gallons a day pumped, but it is said that 19,000 gallons an hour can be pumped
Boughton	,,	Waterworks	58	42	45	55	38	Supply 64,800 gals in 24 hours
,, Hill	,			158' 7"				In Woolwich beds, 27½ ft The total is given as 200 ft 1 in
Boxley	,,	Boxley Grange	348	605	953			In lower greensand
,,	,,	Forstal, for Maidstone Waterworks Co		234' 9'	234' 9"			In Atherfield clay
,,	,,		141¼	120¾	262			,, ,,
,,	,,	Friend's Wood	386½	216'3½'		through chalk 443¾		Into gault stiff blue clay, 8 ft. 6 in.
Brasted	,,	Willis, Esq , The Phillipines		138	138		99	Supply 500 gallons per hour. Another borehole was put down previously, but no water could be obtained
Brenchley	,,	Mr Marchants, Gedges, Matfield	6	201	300		221	Yield 240 gallons an hour in Ashdown beds, 56 ft.
Broadstairs	,,	Waterworks, three wells in chalk Richardson's Pumping Station						Water unfit for drinking purposes; used only for street watering, etc. About 600,000 gallons a month pumped in summer

PARTICULARS OF WELLS—*continued*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Broadstairs .	Kent	Crampton Pumping Station	.		.	.		Water contaminated by admixture of sea-water. Yield 70,000 to 80,000 gals a day
,, ...	,,	Rumfield's Pumping Station		.	..		.	Supply 245,000 gallons a day. Water good
Bromley	,,	Pixfield, Mr Latter's House	.	514	85	429	60	151½ ft above Trinity high water mark Ample supply of water from the chalk
Brompton?	,,	Brompton, Chatham & Gillingham Water-works, Luton		150	10	140		Water rises 75 ft. Yield believed to be over 1,000,000 gallons a day
Brompton	,,	Brompton, Chatham & Gillingham Water-works	151	515′6″		through chalk		Supply 25,000 gallons per hour
Brook .. .	,,	House about ¼ mile S of W of Church	.	102?	102?		overflowed	160 ft. above O D.
Brookland .	,,	Romney Marsh	.	90?	90?	.		Rock
Buckland	,,	Paper Mills, close to the Dour		100	?	into chalk	.	Supply 662,400 gallons a day (100 ft apart)
,, ...	,,	Ditto		145	?	,,		Supply 964,800 gallons a day
Burham	,,	Brick, Lime & Cement Co.	28	91	119		5	Supply 9,000 gallons an hour in Folkestone beds
,, ...	,,	West Kent Gault Brick & Portland Cement Co.		261¼	261¼	.	overflows	Supply 10,000 gallons an hour Tested to 30,000 ,, ,,
Canterbury . ..	,,	Dane John Brewery (Ash & Co.)		400	30	370	.	Supply 2,520 ,, ,,
,, ...	,,	L.C & Dover Railway	30	270	300	..	..	Yield about 5,000 ,,

Canterbury	Kent	St. Dunstan's Brewery	32	218	32	218	25	Yield 3,600 gallons an hour
,, ..	,,	Ditto, second well	9	243	15	237	20	Supply 10,000 ,, ,,
,, . ..	,,	The Monastery, near St. Thomas Hill	150	160½	208½	102	105	
,,	,,	Johnston & Co., Brewers	9	243	15	237	20	,, 10,000 ,, ,,
,, ..	,,	Newby Bros. .	20	121	141		60	,, 2,000 ,, ,,
,, ..	,,	,, ,, . .	6	99	105		66	,, 2,000 ,, ,,
Capel-le-Ferne .	,,	Folkestone Waterworks	30½	130½	5	256	21½	Yield 900,000 gals. in 24 hours
Charing	,,	Bugle, Limited ..	175	422	597		267	,, 400 gals. per hour
,, ...	,,	Mid-Kent Waterworks	175	423		through chalk 332 ft	267	Yield 8,000 gallons an hour
Chartham .	,,	Kent Asylum	261	479		through chalk 734 ft	238	,, 80,000 gallons a day (734 ft. of chalk) (5⅓ into gault clay)
Chatham .	,,	Dockyard .	40	586		through chalk		*No water*
,, .	,,	,, Extension No 1	67	836′6″		through chalk 684½ ft	overflowed	Water overflows and rises to a height of 19 ft above surface The flow was at the rate of 80 gallons a minute
,, ...	,,	,, ,, No 2	45	920′		through chalk 682 ft	overflowed	Supply 300,000 gallons in 24 hours
,, .. .	,,		70	216′2″	21	265′2′		
,, .	,,	Capston Pumping Station	90	155	245			Water found at 138 ft. down. The yearly supply of the whole works is 750,000,000 gallons
Chiddingstone	,,	Mr G F Fag.s	46	55½	101½		44	Yield 6 gallons a minute. In clay 31½ ft.
Chislehurst .. .	,,	Scadbury Park	12	223	114	121	153	Yield 400 gallons an hour
,, ..	,,	Susan's Wood .		86	66	20		..
,,	,,	C H. Kenderdine, Esq	12	218	109	121	153	,, 400 ,, ,,
Chislet .. .	,,	Upstreet Post Office, Messrs. Newby Bros	29	121	141		60	,, 2,000 ,, ,,
,, . ..	,,	Ditto, No. 2 well .	6	99	105	..	66	,, 2,000 ,, ,,
Cliffe	,,	Fort	.	120	76	44	6	
Cliffe at Hoo .	,,	Messrs Curtis & Harvey	.	401	109½	291½	.	Supply about 500 gals. an hour

PARTICULARS OF WELLS—*continued*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Cliffe at Hoo	Kent	Messrs Curtis & Harvey	6	1066		through chalk	level with surface	Supply about 2,000 gals an hour
,, ,,	,,	Messrs Francis & Co	30	30	30	30		
Cobham	,,	Scales Hill		247 ?	50½	196½	219	
Cowden	,,	Messrs Brackett's		158	158			In clay and ironstone. Water found at 49, 62, and 124 ft
Cranbrook	,,	Grammar School		37	37		6 to 10 ft	This well is not used
,,	,,	Railway Hotel, Hartley		331	331		229½	Yield about 3 gallons a minute In Ashdown sand
,,	,,	Sissinghurst Grange		118	118		80	In Wadhurst clay
Crayford	,,	Waterworks for Met Water Board	30	150	?	in chalk	26	
,,	,,	Ditto	34	121	155	,,	27 while pumping	The normal water is given as 15 ft down 30 ft above O D.
,,	,,	Ditto	46	104	150	,,	35 while pumping	Three wells in old chalk pit
Crossness, nr. Erith	,,	Brown's Manure Manufactory		295	85	210		
Cuxton	,,	London and Medway Cement Co.	-23	over 400 ft deep ?		in chalk ?		Yield 25,000 gallons per hour
Darenth	,,	Works of the Met Water Board	74	26½	20	80½	9	Water lowered to 58 ft. by continuous pumping
,,	,,	Ditto	12	238	19	231	2 to 4 ft	Yield 60,000 gallons an hour
,,	,,	Ditto	12	238½	18	232½	2	,, 40,000 ,, ,,

Darenth ..	Kent	Met. Asylums Board, Darenth Wood Imbecile School	246		2	242	216	.
Dartford	,,	C. N. Kidd, Esq.		250	56	194	$9\frac{1}{2}$	Supply 7,200 gallons an hour
,, ..	,,	Daily Telegraph Paper Mills	4	316	17	283		,, 45,000 ,, ,,
,, .	,,	Ditto . .		300	40	260	10	,, 30,000 ,, ,,
,, .	,,	Dartford Gas Works	5	125	46	84	10	,, 2,000 ,, ,,
,, ..	,,	Met Water Board	25	227′ 9″	$26\frac{1}{2}$	225′ 3″	$5\frac{1}{2}$	,, 80,000 ,, ,,
,, ..	,,	Messrs Pigon, Wilkes & Lawrence	8	100	28	80	$9\frac{1}{2}$	,, 1,680 ,, ,,
,, .	,,	Messrs Sanders & Co, Paper Manufacturers		100	22	78	9′ 10″	,, 8,700 ,, ,,
,, ..	,,	E C Powder Co's Works	138	162	150	150	209	,, 5,000 ,, ,,
,,	,,	Met Asylums Board	25	95	52	68	level	,, 8,000 ,, ,,
,, .	,,	London Paper Mills	.	300′10″	27′ 1″	$273\frac{3}{8}$		,, 35,000 ,, ,,
Deptford	,,	Lambert's Brewery	.	178	55	123		
,, ..	,,	Cattle Market, formerly Dockyard	$23\frac{3}{4}$	$32\frac{1}{4}$	51	5		Supply 72,000 gallons a day of 12 hours
,, .	,,	Met Water Board Works	95	155	$22\frac{1}{2}$	$227\frac{1}{2}$	original level 6 ft	..
,,	,,	Twin's Well, in central part of ground	105		25	80	original level 5 ft	
,,	,,	Cold Bath Well, really two wells eastern end of grounds ..	43 98	257 202	16 16	284	$5\frac{1}{2}$ ft	
,, .	,,	Naval School, New Cross Road	50	135	60 ?	25 or more	72	
,, ..	,,	Stowage Wharf .. .	100	320	96	324	19	..
Dover .. .	,,	Castle	.	367	367		10 ft. above O D	Yield 36,000 gallons a day
,, .	,,	Convict Prison, East Cliff	315	616		through chalk 674 ft		Yield 18,000 ,, ,, Water found at 315 ft
,, ...	,,	Priory Railway Station	.	39	39	..	$14\frac{1}{4}$ above O D	Yield 167,000 gallons a day

PARTICULARS OF WELLS—*continued*

Name of Place	County	Locality	Depth					Remarks
			Of Shaft	Of Bore	In Tertiary Strata	In Chalk	To Water from Surface	
			feet	feet	feet	feet	feet	
Dover ..	Kent	Waterworks Castle Hill, three wells each				220½		Yield 1,700,000 gallons a day from all three, rest water level 6 ft. 8 in above high water of ordinary spring tides, or 17 ft above O D
,, ...	,,	Western Heights .		426	.	in chalk	4½ ft above O D	Yield about 168,000 gallons a day
East Barming ..	,,	2½ miles from Maidstone	127	60	187			In blue clay 64 to sand
,, ,,	,,	Maidstone Waterworks		600	600		20	Well supposed to be 600 ft deep
Eastchurch ..	,,	(Sheppy) Sheerings, Mr Higgs?	83	232	315		49	Yield 3,000 gallons an hour
East Langdon	,,	East Kent Waterworks	250			all in upper chalk and flints	234	Supply 100,000 gallons a day; over 5,000,000 gallons a week have been pumped (during construction?)
Edenbridge . ..	,,	Stangrove, N N W of town	18	49	67		22	In Weald clay
Egerton	,,	The Vicarage		70½	70½		62	Lower green sand, Hythe beds or Kentish rag
Elmsted	,,	Vicarage .		243	11	232		Water first reached at 180 ft, a good head at the bottom
Eltham ..	,,	Close to Church		200	103	97		
Erith ..	,,	Messrs Canon and Gaze's Flour Mill	20	130	15	135	18 ft or about O D	Yield 60 gallons a minute, 86,000 gallons a day
,, ..	,,	Crossness Southern Outfall Works	84½	865½		through chalk 646½ ft to gault clay	.	.

Erith	Kent	Do. Second Boring, 1,050 yards south of the former	..	1060	..	through chalk 631 ft to red rock	..	
Erith Marshes .	,,	Brown's Manure Manufactory (now Collin's glue works)		295	85	210		5 ft above O D
,, ,,	,,	Messrs Marshall and Co, now Proctor and Bevington		250' 10"	180	70' 10"		..
,, ,,	,,	Paraffin Works	30	235	141	124	..	..
,, ,,	,,	Messrs Price and Co.'s Mineral Oil Works	41	424	145' 6"	319' 6"	43	.
,, ,,	,,	Maxim Nordenfeldt Guns Co	5	245	5½	244½	12	Yield 38,700 gallons an hour
Erith	,,	British Fire Lighter Co		180	80	100	10	Well sealed for 90 ft.
,, .	,,	Messrs Fraser and Chalmer		290⅓	8	201⅓	11½	Supply 40,000 gallons an hour
,, .	,,	Ditto	17	116	72⅔	60' 4"		,, 30,000 ,, ,,
,,	,,	Erith Oil Works, ½ mile northward of St John's Church		602	81	521	5½	..
,, . ..	,,	Do Second Boring		387	46	341	5½	..
,, ..	,,	Vickers Sons & Maxim		250	5' 6"	244' 6"	12	Yield 38,700 gallons per hour
Farnborough .	,,	Locks Bottom ..		..		.		Chalk at 123 ft.
,, . .	,,	Kent Waterworks	100	100	19	181	14 to 47	..
Faversham .. .	,,	Cotton Powder Co		350	189	161	overflows	Yield 5,000 gallons per hour
,, .	,,	Ditto	8	292	178	122	,,	..
,, .	,,	Abbey Brickyard	.	94	15	79	15 to 20 above O D	,, 30,000 ,, ,, Tested to 35,000 gals. per hour
,, ...	,,	Railway Station	44	302¾	44	302¼	52	..
,, ..	,,	Waterworks	..	113	25	88	25	Yield 200,000 gallons per day (24 hours)
,, ...	,,	Ditto, second well		135	31	104	100	Yearly supply 102,400,000 gals. Highest day's consumption 302,000 gallons
Fawkham	,,	Manor	300	100' 6"	300	100' 6"	300	Supply abundant at first, since given out

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth Of Shaft	Of Bore	In Tertiary Strata	In Chalk	To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Fawkham	Kent	Mr J. J. Hickmott's Brickworks	150	150	150	150		Much water
Folkestone	,,	Gasworks	9	188¾	197¾		40	Yield 8,000 gallons an hour In lower greensand
,,	,,	Metropole Hotel	71½	106½	178			
,,	,,	Ditto, later boring	10	190	200		155	Supply from rock 1,000 gallons an hour
,,	,,	Langton & Co.'s Bry		208	208			
,,	,,	London, Chatham & Dover Railway		126		through chalk	98	9 ft into gault
,,	,,	Public Baths, Foord		100	100		16½	Supply 600 to 1,000 gals. an hr
,,	,,	Waterworks	136	55	191			In lower greensand
,,	,,	Edmundson's Electrical Works		168			48	Supply 1,000 gallons an hour
Foots Cray	,,	Frognal	130		80	50	81	
,,	,,	Sandys Cottage, near Ruxley	78		52	26	75	
Frindsbury	,,	Associated Portland Cement Co	31	792			overflowing	Boring commenced at 560 ft.
,,	,,	Beaver Cement Works	19¾	180¼	19¾	180¼	10	15 ft. above O D Yield 17,920 gallons an hour
,,	,,	Chattenden Barracks, north of Upnor	200	966		through chalk 680 or 682	114	Pumping 5,000 gallons an hour
,,	,,	Whitewall Cement Works: Formby's		810		through chalk 618		Yield 60 gallons a minute Into gault 192 ft.
Gillingham	,,	Darnett Mess ..		218	170	48		

Gondhurst	Kent	Village Well		162				Leaving off in marl Enough water of good quality
Grain, Isle of	,,	Fort	180	140	320	.	20	
,, ,,	,,	Rose Court Farm	9	301	301	.		.
Gravesend	,,	Denton Hospital	3½	106½	68	42	8	
,,	,,	Electric Light Station		150	17	133	10	Supply 7,000 gallons per hour
,,	,,	London, Chatham & Dover Railway	6	94½	23½	77	56	,, abundant
,,	,,	Messrs Russell's Brewy	16	104	16	104	1½	,, 4,000 gallons an hour
,,	,,	Ship and Lobster Tavern, Milton	5	60	65			
,,	,,	Thomas's Paper Mill	11	135	2	144	12¼	Yield 32,000 ,, ,,
,,	,,	Waterworks		134	66	68		Supply 250,000 gallons a day ,, 200,000 gallons in winter According to the sixth Report of the River Pollution Commission the well is 200 ft deep
,,	,,	Ditto, two later wells	160 183		92 107½	68 75½		
,,	,,	Sanatorium, White Hill	12	223			146	Yield 600 gallons an hour
,,	,,	Bruce Barclay, Esq	6	04	23	77	56	Supply abundant
Greenhithe	,,	Hunter Taylor and Spoor's Cement Wks		162	50½	111½		Tested 15,000 gallons an hour
Green St Green	,,	Mid-Kent Waterworks	32	220	14	238	31′ 6″	Supply 30,000 gallons an hour Supply increased by blasting
Greenwich	,,	Observatory, "Flansteeds Well"		80	75	5		To chalk, 75
,,	,,	Ordnance Wharf	50	272	164	158	18	
,,	,,	Union Workhouse		84	54	30		
,, East	,,	Portland Cement Works		65		.	.	To hard stone
,,	,,	Beehive Brewery, Church Street	10	270?	130	150		Supply continuous and abundant
,,	,,	Infirmary		180	30	150	.	..
,, North	,,		.	262	62	200	.	Supply 11,000 gallons an hour Water brackish
Hadlow	,,	Style's Place Brewery, nearly a mile S.S E of the Castle		838½			overflowed	Water overflowed 24 ft above ground (at the rate of 40 gals. a minute) into Ashdown beds?

PARTICULARS OF WELLS—*continued*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Halling	Kent	Mid-Kent Waterworks	56	315′ 6″	.	right through chalk	..	Supply 24,000 gallons per hour
Halstead .	,,	Public Well for Sevenoaks R S A	19	365	19	365	..	Yield 1,700 ,, ,,
Ham Street (Orlestone)	,,			150				At 65 ft. great quantity of gas At 70 ft. some hard oak partly carbonised At 74 ft. 2½″ of coal, soft At 110 ft about 4½″ hard bright coal 12 ft. of gault (clay) bored through At 122 ft. about 4″ of coal, bright and hard
Harty	,,	Sheppey, Elliott's House	..	179	179			In London clay
,, ...	,,	Sayes Court .	.	178	178	..		In blue London clay
Hawkhurst . ..	,,	Babies Castle	..	231	231		150	Supply 14,000 gallons in 24 hrs.
,, ..	,,	Railway Station .. .	100	180	280		120	,, 1,080 gallons an hour
Herne Bay	,,	Mr. Hardiman's .		50	50	..	12	Yield 400 ,, ,,
,, ,, .. .	,,	Gas Light and Coke Co.	20	380	196	204		,, 2,000 ,, ,,
,, ,, .	,,	Waterworks ..	151	270	301	..	..	In Oldhaven, Woolwich and Thanet beds
,, ,, ..	,,	Newer Works at Ford, three wells, No. 1	95	284	110	269	.	Galleries at 71 ft
,, ,, ..	,,	Ditto, No. 2 .. .	170½		109	61½?	26	Yield 183,600 gallons a day
,, ,, ...	,,	,, No. 3 .. .	..	174	110	64	90 ft down when pumping	

Hever ..	Kent	The Castle . .	10	363	373		98	Yield 7,500 gallons an hour
Highham .. .	,,	Higham and Hundred of Hoo Waterworks	160	?	..		..	Pumping 6,000 ,, ,,
High Hockley	,,	For Hon A McGarel Hogg	80	82' 6"	162' 6"	..		In Weald clay
Hinxhill	,,	For the supply of Willesborough, ½ mile N W. of Church	50	152	202		24½	In Sandgate beds, 22 ft
Hoo Fort ..	,,	Fort . ..		461	110¼	350	..	
Hoo Point ..	,,		..	188	140	48	..	
Horley	,,	Mid Kent Waterworks	12	238' 7"	18	232' 7"	2'	Supply 60,000 gallons per hour
,, ...	,,	,, ,,		250	19	231	2' 4"	,, ,, ,, ,,
Hormonden ..	,,	J T. Fairbank ..	100	180	280 '	.	120	,, 1,080 ,, ,,
Iwade . .	,,	Chitney Hill .		284	284		8	Through blue London clay
,,	,,	Kings Ferry ..	..	.	.		.	London clay to 200 ft.
Kemsing	,,	Trial boring for Seven oaks Water Co		250	250		41	292 ft above O D. Yield 1,100 gallons an hour
Lamb Abbey	,,	Or Lamorbey House, Dr. D Scott's		146	116	30	17	
Lee ..	,,	Grove Park, New Workhouse	..	243	142	101		
,, ...	,,	Steam Laundry, Miss Austin's	..	200	113	87	17	,, 3,000 ,, ,,
,,	,,	Mr Bray's Steam Laundry, High Road	3	90	46	47	10½	,, 750 ,, ,,
Lewisham ..	,,	Brockley, Watney's Bry	40	280	99	221	40	,, 1,800 ,, ,,
,, ..	,,	Hither Green Park Hospital (two borings)	94	138	232	.		To chalk
,, ..	,,	Lower Sydenham, Bell Green	.	217	200½	11		About 9 ft. above O.D
,, ..	,,	Proposed New Brewery, S E of cemetery, 1½ mile from waterworks well at Deptford		320	99	221	..	,, 30 gallons a minute
Lower Halling .	,,	Near Birchfields	15	127	142	..	14½	
,, ,, ..	,,	Mid-Kent Waterworks	50	326' 11"	.	through chalk 138 ft.	12 ft above O D.	Yield from lower greensand 38,000 gallons per hour

PARTICULARS OF WELLS—*continued*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Lydd	Kent	Holmston Range		402′ 6″ Hastings beds			9	Yield 90 gallons an hour? Abandoned on account of water being salt
Maidstone	,,	Burnham Brick, Lime and Cement	20	119	139?		5	Supply 9,000 gallons an hour
,,	,,	Brenchley's Brewery	100	69	169		6	,, abundant
,,	,,	Foley House, more than a mile N E of All Saints Church	164	928			.	In Hastings beds, practically no water, yield 1,200 gallons in 24 hours
,,	,,	Medway Mills		200	200		125	Yield 9,000 gallons an hour
,,	,,	Mr Hayward's, Milton St	49	47	96		49	,, 400 ,, ,,
Malling ..	,,	T Phillips, Esq, Abbey Brewery	50	94	144		45	,, 3,000 ,, ,,
Marden .	,,	Jude, Hanbury & Co		355	355		5 ft above	,, 1,000 ,, ,,
Margate	,,	Corporation	15	835		through chalk	61	
Minster	,,	Ebbsfleet Farm		170	92	78	14	,, 10 ,, a minute
,,	,,	Sheppey, Rushenden Hill		401	400	1	31 ft below O D	Yield 3,000 to 3,500 gallons an hour
,,	,,	South Lees Farm, Crown Lands		477	459	18	50	Water got in the green sand at 284 ft
,,	,,	Neatscourt, Crown Lands		221	221		40	Fair supply of good water
Minster, Sheppey	,,	Union Workhouse	$262\frac{3}{4}$	300			$219\frac{3}{4}$	Yield 4,000 gallons a day
Monkton	,,	For Mr. Pettman	6	144	135	15	15	,, 500 ,, an hour

Murston	Kent	Milton Waterworks (*Eastern well*) two wells		109	6	103	64	Supply 24,000 gallons per hour
,,	,,	Ditto (*Western well*)		169	6	163		,, 18,000 ,, ,,
Northbourne	,,	Betteshanger Park & Lord Northbourne's Estate		210¼		in chalk	22½	216 ft above O D Yield 105,000 gallons a day
Northfleet	,,	Messrs. Pope & Co. Brewery	65	285		350	74½	Supply abundant
,,	,,	Gasworks	8	55	8	55	8	Yield 12 gallons a minute
,,	,,	Lawrence & Wimble's Cement Works		70	14	56	12	,, 60,000 gallons a day
,,	,,	Paper Mills					9½	Chalk 101 ft
,,	,,	Red Lion Works, Tolhurst & Son	14½	250	14½	250		
,,	,,	Tower Cement Works	9	126½	65 +	70′ 2″	14½	Yield 3,500 gallons an hour
Oare or (Ore)	,,	Cotton Powder Co		193	193			Water over the surface 28 gals a minute to chalk
,,	,,	,, ,,	6	344	193	157	1	Supply 4 000–5,000 gals. an hr
,,	,,	,, ,,		300	175	122		
,,	,,	Ditto, Works		350	189	161	overflows	
,,	,,	Harty Ferry, Mining Machinery & Improvements Co	13	239	184	68		
Otford	,,	Sevenoaks R D C ..	19	64	83		9½	Supply 20,000 gallons a day
Pembury	,,	Tunbridge Workhouse	108	199	307			Abandoned in 1887
,,	,,	Waterworks, Tunbridge Wells, No 1		350	350		100	Supply 12,000 gallons an hour
,,	,,	Ditto, Basestts Farm No 2	12	388	400			Yield 20 000 ,, ,,
,,	,,	Tunbridge Wells Waterworks, No 3		350	350			,, ,, ,,
,,	,,	Ditto, No 4	10	325	335		54	Supply from two wells, between 25,000–30,000 galls an hr
Pevensey Bay	,,			84′ 6″	84′ 6″		30	In limestone rock 4′ 6″, 800 gallons per hour
Plumstead	,,	Baths		420	34	386		

PARTICULARS OF WELLS—*continued*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Plumstead	Kent	Boston (Bostall) Heath, near Woolwich		200	130	70	.	.
,, . ..	,,	Brewery	82	49	52	79	.	.
,, (Common)	,,	.		144	120	24		..
,, ,,	,,	Waterworks .	128	509	74	563	70	Yield over 400 gals. a minute
Rainham .. .	,,	Falcon Cement Works, Burge & Barrow	36	106	65	77		,, 30,000 gallons an hour
,, . ..	,,	Public Supply	..	906¾		through chalk 480		Excellent water Supply from the sand, 17,000 gallons an hour In lower greensand 20¾ ft
Rochester .. .	,,	Messrs. Rooth & Co., Borstal (2 18 in borings, 200 yards apart)		55	8½	46½		Yield 15,000 gallons an hour from each
,, ...	,,	Electric Light Works, on the bank of the Medway	22	326¾	46	302¾	12	Yield 36,000 gallons an hour Total given as 10 ft less
,,	,,	(Lion ?) Brewery, C. Arkcoll & Co	25	360	11	374	10	Yield tested to 10,000 gallons an hour
,, ...	,,	Rochester, Chatham & District Laundry Co	14½	39½	25½	28½	14½	
,, .	,,	Messrs Peters Bros., Cement Works	20	312½			18	Supply 40,000 gallons an hour
Saltwood .	,,	..		189	189		99′ 8″	..
,, ..	,,	For Hythe Waterworks	108	49	157		74½	In November 1899 the yield varied from 24,432 to 32,000 gallons in 24 hours

Saltwood	Kent	Sandling Park, S W of house	36	91½	127½	..	.	.
Sandwich	,,	Waterworks				.		Supply 30,000 gallons per hour
Sevenoaks	,,	Bat and Ball Station, L. C. & D. Railway	29	38½	67½		overflows	20 ft. above ground. About 60,000 gallons a day are used
,, . ..	,,	Gasworks .. .	12	128	140	.	overflows	14 ft. above ground. Supply 12,000 gallons an hour
,, .. .	,,	Mr. J. Golding's Brewery, near railway station		87½	87½	..	overflows	10 ft. above surface, the rate of 1,500 gallons an hour. Pumping at 7,000 gallons an hour
Sheerness ..	,,	Dockyard	330	650¾	510	470¾	53	Yield 675 gallons an hour. About 13 ft above mean water level
,, ..	,,	Fort Townshend, old well	336	112		..	75	..
,, .	,,	Ditto, new well, about 23 ft from the old well	204	602	501	305	80	Yield 4,000 gallons an hour
,, . .	,,	New town well ..	335	470	502	303	..	Daily supply 230,000 gallons
Shoreham ..	,,	The Place	25	450	..	through chalk 200 ft	12 ft. above	
Shorne	,,	British Uralite Co, westward of Higham		350	155	195		.
Sittingbourne	,,	Lloyd's Daily Chronicle Mills		520	13	507	overflows	Overflows into mill stream at the rate of 334,560 gallons in 24 hours
Snodland .	,,	Mr. S Crowhurst's .	..	147½	147½		29	..
Southborough ..	,,	Waterworks ..	9	424½	..	.	102	It is said that the yield is 1,500 gallons an hour
Southfleet	,,	Met. Water Board's pumping station	100	100	16	184	48	..
Stone . .	,,	E. C. Powder Co. ..	138	162	150	150	209	Yield 5,000 gallons an hour
,, ...	,,	Horns Cross ..	..	115	45	70		
Stourmouth .	,,	Stourmouth House ..	.	159	138	21	.	
Strood	,,	Stewart Bros & Spencer's Oil Mills	..	757	.	through chalk 505 ft.	overflows	Through a small pipe to 45 ft above ground ..

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth: Of Shaft	Of Bore	In Tertiary Strata	In Chalk	To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Strood	Kent	Waterworks						Well in chalk, 132 ft with heading Yearly supply 97 million gallons Highest day's supply 302,000 gallons
,,	,,	Wickam Cement Works	40	42' 11"		all chalk 82' 11"	16¼	
,,	,,	Ditto, No 2	25	46	3' 5"	67' 7"	14' 8"	
Sturry	,,	Wootton, Esq , Tile Lodge Farm	11	289	210	79	70	Supply 140 gallons per hour
,,	,,	Mrs. Thornton's (near the bridge)		53	53		overflows	
Sundridge	,,	Ovenden House		350	350		78	
Tenterden	,,	A R Ticehurst, Esq		268			51	
Thanington	,,	Canterbury Waterworks	36½	473		all chalk 599½	19	Yield 1,500,000 gallons a day
Tonbridge	,,	Bartram's Brewery		23½	23½		13½	Yield 7,200 gallons an hour
,,	,,	Hildenborough, South-wood		547	547		72	Abandoned without getting a supply
,,	,,	Messrs. White & Sons		23½	23½		12	Yield 600 gallons an hour
Tunbridge Wells	,,	E and H Kelsey & Co , Brewery	117	787	787		220	Supply 1,500 gallons an hour
,, ,,	,,	Corporation	10	325	325		54	,, 25,130 ,, ,,
,, ,,	,,	Hughes, Esq , Prospect Lodge	6	64' 6"			20	,, 1,000 ,, ,,
,, ,,	,,	L B. & S. C Ry	89	516' 3"			20	,, 7,000 ,, ,,
,, ,,	,,	High Brooms Laundry		217	217		143	,, over 1,000 gallons an hour

Waldershare	Kent	Mr. W. C. Payne's		310	3	307	..	
Westerham	,,	Pumping Station of Met Water Board	70	70	140		32	Average supply 25,000 gallons a day All in lower green sand
West Malling	,,	Phillip's Abbey Brewery	50	94	144		45	Supply 3,000 gallons an hour
West Wickham .	,,	Pumping Station of the Met Water Board	62	138	11	189	51	,, 800,000 gallons a day
Whitstable	,,	Waterworks (two wells), No 1	72	328	240	160	35	Yield 220,000 ,, ,,
,, . ..	,,	Ditto, No. 2 well .	28	351	215	164	13½	
Wilmington .	,,	Pumping Station of the Met Water Board, No. 1	80	122	20	176	63	Water level, with both engines pumping about 63 ft.
,, .	,,	Ditto, No 2 . . .	94	108	20	176	63	Yield 5,500,000 gallons a day
Wingham	,,	Margate Waterworks	140 in chalk				25 to 27	Tested to 3,000,000 gallons a day
,, . ..	,,	Tuff and Miskin .. .	20	42	62			
Woodnesborough	,,	Sandwich and Eastry Waterworks	9½	119	14	128½	33½	Yield 450 gallons an hour
,,	,,	Anson and Shenton	56⅔		27	29⅜		,, 720,000 gallons a day
Woolwich ..	,,	District Chemical Works	3	168'10"	40	131'10"	.	,, 3,020 gallons per hour
Wouldham .	,,	Wouldham Hall and Burnham Cement Works	20	332½		.	18	,, 40,000 gallons an hour
Wroxham	,,	Near Wrotham at the base of the North Downs		226	..	through chalk 140	130	
Wye	,,	South Eastern Ag College		266		..	10	Above ground at the rate of 8 gallons a minute

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks

KENTISH COAL MEASURES

Shafts and Trial Borings for Coal.

Name of Place	County	Locality	Of Shaft	Of Bore	In Tertiary Strata	In Chalk	To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Alkham (or Swingfield)	Kent	Elinge Boring	.	1,805′ 8″		through chalk 574 ft.	.	Into Coal Measures, dark shales and sandstone, 129′ 4″, 400 ft above O.D.
Barham (or Womenswold)	,,	Ropersole Boring on the high road between Canterbury and Dover		2,129′ 0″	.	through chalk	..	Into Coal Measures, 548¼ ft., 400 ft above O D
Brabourne ..	,,			2,010′ 7″				88′ 5″ into Devonian or old red sandstone, dark grey dense clayey rock
,,	,,		.	2,004′ 0″		.	..	In ditto 82′ 7″ (322 ft. above O D)
Coldred . .	,,	The Wadershare Boring		2,243′ 1″		through chalk 820 ft.	..	Into Coal Measures 849′ 0″, 325 ft. above O.D.
Elham . ..	,,	Ottinge Boring .	.	836½	.			Into Kimeridgian 108′ 6″
Hothfield . ..	,,	West of Parsonage Farm, a little southward of Hothfield Station,		809′ 0″		..	..	Into Wealden and Purbeck beds, into Portlandian 17 ft., about 200 ft. above O D.
Houghham	,,	Dover Collieries, No. 1	.	510′ 8″	..	through chalk		Into Hastings beds ? 43′ 2″
,, . ..	,,	Simpson's Pit, No. 2	..	2,308′ 2″	..		.	In Coal Measures 1,152′ 2″
Nonington ..	,,	The Fredville Boring	.	1,505′10″	..	through chalk 860 ft.	..	In Coal Measures 137′ 4″

Penshurst .. .	Kent	Mid-Kent Coal Co.		1,867′ 0″		..	..	Into Portlandian 116⅜ ft.
Pluckley	,,	On the Northern side of the Railway, a little east of the Station		1,699′ 0″		..	..	Into Kimeridge clay 775 ft. 2 in
Ruckinge or New-church	,,	Langdon Farm	9	555′ 6″	.	.	..	Into Hastings beds 412½ ft
Wrotham	,,	.	.	858′ 0″		..		About 200 ft. above O.D., into Wealden beds, 139 ft.
Acton	Middlsx.	Brewery		483	286	197	67	
,, East . ..	,,	,, .		..	.	.		Through blue clay to sand 24 ft Water flowed up to top
,, ,, ..	,,	Friar's Place . .	..	350	340	10	..	..
Albert Gate	,,	Hyde Park Court	11	439	284	166	110	Supply 8,000 gals. per hour
Alperton . .	,,	N of Ealing . .	195	205	220	180	85	..
Bayswater	,,	Sovereign Brewery .	35	354	299	90	155½	.
Berkeley Square	,,	Berkeley House ..	.	450	239	211	183⅔	,, 3,192 ,, ,,
Berners Street	,,	Messrs Schweppes	10 cellar	303	160	153	151	..
Bethnal Green ..	,,	Workhouse	82	219	134½	166½	82	
Blackfriars ..	,,	Royal Hotel	217	152	217	152	94	
Black Horse Yard	,,			257	182	75		To chalk 182 ft.
Blackwall	,,	Trinity Wharf	64½	183½	236⅝	11½	13	..
Bow Road .. .	,,	City of London Infirmary		248	178	70	80	Supply 15,000 to 20,000 gals a day
Brentford .. .	,,	A boring .		225	225	..	..	Into blue London clay, 200 ft.
,, . ..	,,	Booth's Distillery ..	.	415	315	100	..	4,800 gallons per hour
,, Old	,,	Mr. White's .	.	337	309	28	..	To chalk 309 ft
Broad St, Golden Sq.	,,	Lion Brewhouse	.	216½	191½	25	..	
Bromley-by-Bow	,,	Messrs Berger & Co.'s Starch Works	176	148	174	150	.	.
,, ,,	,,	Imperial Gasworks .	52	448	154½	345′ 6″	32	
,, ,, ..	,,	Joseph Fosters ..		120	120	..	.	..
,, ,, ..	,,	Three Mills Distillery	82	168	145	105	44	Water overflows into the shaft, 58 ft down, at the rate of 2,700 gallons per hour

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Brompton, West .	Middlsx.	Brewery, 250 Fulham Road	90	200	290 ?	.	.	No record of stratas
Caledonian Road	,,	Crosse & Blackwell ..	20	430	227½	222' 6"	210	Supply 3,500 gals. per hour
,, ,,	,,	Slaters Ltd.		451	197	254	191	..
Camden Town ..	,,	..	235	over 115	310	over 40	190	..
,, ,, ..	,,	Idris & Co., Ltd. ..	11' 6"	399' 3"	151	259' 9"	160	,, 4,320 ,, ,,
Carey Street .. .	,,	New Court	basement 9	401	220	190	210	,, 2,280 ,, ,,
Charing Cross .	,,	Messrs. Cox & Co.'s Bank	188½	72½	235¼	25⅗	125	
Chiswick . ..	,,	Chibnal's Bakeries					.	..
,, ...	,,	Fuller, Smith & Turner	176	227	287	116	180	,, 4,000 ,, ,,
				512	305	207	.	
,, ..	,,	Sanderson & Sons		280	264	16	59	,, 4,000 ,, ,,
Chelsea	,,	King's Road .		.				Chalk touched at 245 ft. below Trinity high water mark
,, ...	,,	Munday's Brewery		394	394	.	200	Mostly through blue (London) clay
Chiswick	,,	Horticultural Society Garden (now Royal Avenue)	30	299	261½	67½	overflowed	6 gals. a minute, 16 ft above ground
City	,,	Baltic Exchange ..		450	211	239	117	Supply 6,200 gals. per hour
,, ...	,,	Bank of England .	13' 6"	436' 6"	234	216	174	,, 10,000 ,, ,,
,, ...	,,	Montreal .	.	37?	234	136	165	,, 600 ,, ,,
,, . ..	,,	Barker & Sons .. .	12	338	203	147.	111	,, good
,, ...	,,	Bishopsgate House	.	402	223' 6"	178' 6"	162	,, 1,400 ,, ,,
,, ...	,,	Broad Street House		340			.	,, 2,000 ,, ,,

City	Middlsx	Cannon Street House	10	470′ 6″	269	211′ 6″	175	Supply 1,500 to 1,700 gallons per hour
,, .	,,	,, ,,	9	432	256	176	172	Supply 1,500 gals per hour
,, ...	,,	City Offices Co., 26 Gracechurch Street	10	416	235′ 2″	190′10″	173	,, 3,000 ,, ,,
,, ...	,,	Dashwood House, Old Broad Street	10	405	212	203	160	,, 1,000 ,, ,,
,, ...	,,	East India Chambers	6	394	246	154	160	,, 1,200 ,, ,,
,, .	,,	Great Eastern Hotel, Liverpool Street		500	203	297	144	,, 3,000 ,, ,,
,, . .	,,	Leadenhall House .	6	394	220	180	158	,, 1,500 ,, ,,
,, ..	,,	,, ,,	10	390	224½	175-6	157	,, 1,500 ,, ,,
,, ..	,,	Ocean House, Upper Thames Street		400	207	193	134	, 2,500 ,, ,,
,, .	,,	Old Change	cellar 11	389	250	150	201 from street level	,, 400 ,, ,,
,, ...	,,	,, ,, ..	10	390	235	195	188	,, 2,500 ,, ,,
,,	,,	Salters Hall .	12	388	206	194	181	,, 1,500 ,, ,,
,, .	,,	Shorters Court ..	10 cellar	392	231	171	171	,, 1,200 ,, ,,
,, . .	,,	Winchester House	10	440	207	243	146′ 6″	,, 8,000 ,, ,,
Cricklewood .	,,	Imperial Dry Plate Co		476	275	201	134	,, 4,000 ,, ,,
City Road ..	,,	Champion's Vinegar Works			150	?	123	100 gallons a minute pumped
Clerkenwell .. .	,,	Nicholson's Distillery, 193–199 St. John's St		..		.	60	Supply 10,000 gallons per hour
Cold Bath Fields ..	,,	House of Correction	through out 152 ft	..	132	20		Supply 150 gallons a minute
Cowley	,,	Yewsley Vicarage	16	174	175	15	overflows	At the rate of about 5 gallons a minute, 4 ft. above surface
,, ...	,,	Mr. J. Cluttons (*Yewsley*)		160	150	10	8 ft. above ground	..
Cripplegate . ..	,,	Messrs. Warners, Crescent Foundry	120	156½	166½	110	122	Average supply 8,000 to 10,000 gallons a day, 6 days a week
Ealing	,,	Castlebar Hill ..	..	360	360	.	.	To chalk 360 ft.

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Ealing ..	Middlsx	Grand Junction Waterworks	6	464	320½	149½	49½	..
,, ..	,,	New Baths	5	596' 8"	328' 8"	273	36	.
Edgware	,,	Public Well	90	200	130	160	90	
,, (near)	,,	Convalescent Hospital	125	189	154	160		..
Edmonton	,,	De Ritter, Esq	8	292	139	161	10	Supply 1,980 gallons per hour
,, ..	,,	Eley Bros ..	7	393	122	278	62	,, 6,276 ,, ,,
,,	,,	New River Co, Highfield Row	Shaft and cylinders 153' 6"		114' 11"	38' 1"		
,,	,,	.			..		water overflowed	To chalk 150 ft.
Enfield	,,	New River Co, Hoe Lane, Forty Hill	192	9	101½	99½	.	..
,, ...	,,	End of Turkey St, near the road to Ware	.	140	140		overflowed	To chalk 140 ft
,,	,,	Saw mills, in the town	35	131	123	43		
,,	,,	Highway					overflowed	To chalk 130 ft
,,	,,	Royal Small Arms (or Ordnance) Factory (*second well*)	Iron cylinders for 25 ft brick shaft for 33 ft	407' 3"	146' 3"	319	3' 2"	Yield 5,000 gallons a day
Euston Road	,,	Midland Rly. Station	140	286	136	290		Supplies the hotel
Finchley ..	,,	Common	217	40	257		.	Bored to water (*London clay*)

Finsbury ..	Middlsx	Hill Street, Messrs Robinson's		..	..	..	..	Chalk at 172 ft.
Fishmongers' Hall	,,	Northern End of London Bridge		237	237	..	..	To chalk
Fulham .. .	,,	Bishop's Palace, bored in Courtyard	27	343	250	120	..	Well is now disused, original depth 316' 0", deepened to 370 ft in 1862
,, ..	,,	Old Cremorne Gardens	120	290	249½	160½	51	
Grays Inn Road	,,	Messrs. Cubitts	114' 4½"	164' 7½"			130	Good supply; two wells 82' 7½" apart
,, ,,	,,	,, ,,	162' 0"	154	137½	178½	130	
,, ,,	,,	76 Swinton St, Messrs Huskisson's	..		..			To chalk 143 ft.
Grays Inn Square	,,	Perkins & Sons	12	288	153	147		Yield 3,000 gallons per hour
Greenford	,,	Mr Roberts	176		172	4	..	To chalk 172 feet
,, Green	,,	Near Harrow	65	295¼	144¼	216	.	
Hackney Road	,,	Messrs Chandler and Sons (*two wells*)	14' 6"	385' 6" 400	147 232	253 168	93 115	Supply from both wells 10,000 gallons per hour (*minimum*)
,, ,, .	,,	Three Crowns Brewery		120	120			.
,, Wick .	,,	Atlas Works ..	•	206	101½	104½	..	.
Halton	,,	Sir F Pollock's (West of Hounslow)	..	270	270			..
Hammersmith	,,	Spring Cottage	14	286	255	45	.	Water rose to surface at the rate of 90 gallons a minute
Hampstead .	,,	Brewery	340	260	444	156	325	..
Harefield . ..	,,	New Years Green Farm		63	63		48	..
,, . .	,,	,, ,, ,,	66	105	76	95	60	..
,, .. .	,,	Paper Mills .	20	300	20	300		
,, Park .	,,		shaft throughout 22		22	.	5	..
,, ..	,,	The Shrubs ..	shaft throughout 120	.	120			Abandoned, no water
,, .. .	,,	Spring Well in bottom on Colne Valley	30	220	22½	227½	22½	.

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Harrow .	Middlsx	London and North Western Railway		163	72	91	..	
,,	,,	Sudbury Grove ..	133	50	183		60	
Hayes	,,	Malling, behind the Adam and Eve Inn (on High Road)		215	173	42	10	..
Hendon .	,,	The Hyde, Kenton Grange (Mr J Gwynne's)	26	196½	99½	123	37	.
,, . ..	,,	The Hyde, Edgware Road (Mr Robb's)		137′ 10″	100′ 10″	37		.
,, . .	,,	Union, near Edgware	85	240	128	197		
,, . .	,,	Messrs Schweppes	100	210	125	185	74	Supply 4,000 gallons per hour
Highwood Hill	,,	Between Edgware and Totteridge	80	155	235			In Reading beds, abandoned
Hillingdon	,,	Union Poor House	.	251	205½	45½	39	..
Hornsey	,,	Campsbourne, New River Co	215	20	166½	68½	60	..
,, .	,,	The Printer's Alms-houses, Wood Green		190	190	.		To chalk
,, .	,,	Near Palmers Green and the New River		200	165	35	60	..
Houndsditch ..	,,	Grave Lane	cylinders and shaft	123′ 4″	123′ 4″		(24′ 11″	In gravel)
Hoxton .	,,	Cambrian Brewery, Turner Sq	14	238	159	93	120	..
,, .	,,	St Luke's Workhouse, Shepherdess Walk	155½	293′ 1″	151′ 1½″	297	131½	Pump 100 gallons a minute

Hoxton	Middlsx	..	..	151	151	..	..	To chalk
Isle of Dogs .. .	,,	Cumberland Oil Mills, W. G Armstrong & Co	38	21	59	..	..	In Woolwich beds
Isleworth . ..	,,	Lord Cassilis .	.	290		.	..	Water rises 30 ft. above the ground at the rate of 30 gallons a minute
Islington Vestry	,,	Hornsey Road Baths		450	192	258	165	Supply 10,000 to 14,000 gallons per hour
Kensal Road ..	,,	Wilts United Dairies.			..	.	..	
Kensington (near)	,,	Mr. Bird's .		421	286	135	30	To chalk, 286 ft
,, South	,,	Albert Hall Mansions (Mr T Hussey)	36	384	297	123	116	.
Kilburn .. .	,,	London and Provincial Steam Laundry		480½	330½	150	.	Water good and plentiful
Kingsway .	,,	Craven House		400	164	236	190	Supply 1,400 gallons per hour
Knightsbridge ..	,,	Harrod's Stores (Brompton Road)	13′ 8″	486′ 4″	275	225	140	,, 9,300 ,, ,,
Ladbroke Grove Rd.	,,	Marylebone Infirmary	234	268	289	213	90′ 8″ overflow	..
Littleton House .	,,			520	520			Water flowed continuously at the rate of about a gallon a minute to a height of about 16 ft above the ground
,, ,, ..	,,	New well		700	570	130	..	To chalk, 570 ft. Water rose from 700 ft. to 20 ft above level of Thames
Lombard Street ..	,,	St Mary's, Woolnoth		253	253		80	To chalk
London Docks .	,,			144½	144½		.	..
Lower Clapton	,,	Hackney Baths	15	386	138	263	103	Supply 10,000 gals per hour
Maida Vale .	,,	Welford & Sons, Ltd	11	507	276	242	157	Supply 4,000 gallons per hour. Water level in 1909, 207 ft.
Mansion House	,,	..		.		..		To chalk 240 ft.
Marylebone Road	,,	Marylebone Workhouse	188	178	188	178	153½	Supply abundant
Minories	,,	London & Blackwall Railway Co.		177	177		88	Afterwards bored down to chalk. Not used now
Mortimer Street ..	,,	Great Portland Street	.	400	168½	231½		Top of well 10 ft below level of road
Neasden	,,	Great Central Railway	5	370	180	195	70	..

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth					Remarks
			Of Shaft	Of Bore	In Tertiary Strata	In Chalk	To Water from Surface	
			feet	feet	feet	feet	feet	
Northall ..	Middlsx.	Vicarage		164	164		4	To stone and water
Northolt	,,	Village well (for Mr F Gurney)	20	214	130	104	.	Yield 500 gallons an hour
Norton Folgate	,,	Mr. Hendrie's		175	175		72	..
Norwood . ..	,,	Near Hanwell, Vitriol Works		414	325	89	.	Water rose to the top? (shaft through London clay 280 ft)?
Notting Hill .	,,	Messrs Campbell Johnstone		400	223	177	80	Supply 4,500 gals per hour
,, ,,	,,	Eastman and Sons	11	389	235½	164' 6"	70	,, 5,760 ,, ,,
,, ,,	,,	Norland House	236	260 through rock	496	.	overflowed	46 gallons a minute
,, ,, .	,,	Notting Hill Brewery	5' 6"	384' 6"	230	160	109	Supply about 3,000 gallons per hour
Old Broad Street	,,	Gresham House		499	250	249	-	To chalk 250 ft.
Pall Mall .	,,	Reform Club	170	100	170	100 sand & chalk	130	
Piccadilly	,,	Walsingham House		415	275	140		..
,,	,,	Burlington House, Royal Academy		450	162	288	152	Supply 1,644 gallons per hour
Pimlico	,,	Grosvenor Hotel	20	395	262 2"	152' 10"	83	Yield from chalk 57 gallons a minute
,,	,,	Victoria Station, L B. & S C. Railway	140	190	264	66	7	Good supply of water from the sand springs
Pinner	,,	Commercial Travellers' School	32	110	45	97		. ..

Pinner	Middlsx.	D. Carnegie, Esq	242	60½	237½	65	240	..
,,	,,	West End	.	.	.		.	To chalk, with a plentiful supply of water, 70 ft.
Ponder's End	,,	Messrs Gronts & Co 's Crape Works		211½	106½	105	2	
Poplar	,,	High Street		140				In gravel, 70 ft.
Portland Place	,,	Langham Hotel	152	213	164	201	about 152	Supply plentiful (30,000 gallons a day)
Regent's Park	,,	Mr. Fulks		182	182			42 ft. into red clay
Regent Street	,,	Piccadilly Arcade (new)						
,, ,,	,,	Piccadilly Hotel		450	228	222	172	Supply 5,040 gallons per hour
Ruislip	,,	Northwood Vicarage	105		45	60	9	.
,,	,,	Northwood Railway Station		150	61½	88½		
Russell Square	,,	Northern Side	130	100	130	100	130	
St. George's Workhouse	,,	Near Thames Tunnel		256	144	112		To chalk 144 ft.
St. James' Street	,,	White's Club House		235	235		45	93 ft in red clay (Reading beds)
St. James'	,,	Conservative Club	..			.	300	
St Luke's	,,	In Old Street, close to church	163	..	163			In Reading beds
,,	,,	Old Street (Mr Moore's)	153	125	153	125	124	.
St. Martin's le Grand	,,	General Post Office (new building)	183	464	259	388	122	58 ft above O D Yield 2,291 gallons per hour
Shadwell	,,	Ice Factory (Linde British Refrigerating Co)	44	375	145	274		..
,,	,,	Union St , Mr Brown's						To chalk 184½ ft.
Shepherd's Bush	,,	Mr Brydges	.	318	252	66	.	,, 252 ft.
,, ,,	,,	Albion Brewery, next to Metropolitan Railway Station	150	233	224	159	45	
Shoreditch	,,	Workhouse, Kingsland Road	..	263	157 ?	106 ?	.	..
Smithfield	,,	St. Bartholomew's	..	250	220	30	..	,, 220 ft.
,,	,,	Cold Air Stores	..	160	160	.	..	,,
Southall	,,	Mr. Deloitte's	..	330	300	30	15	,, 300 ft

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Southall	Middlsx	Vitriol Works	..	300	252	48	6″ above ground	Supply 35 gallons a minute Water rose 6″ above the ground
,,	,,	Norwood Waterworks	130	390	271	249		10 ft above O.D.
Southgate	,,	Betstile, New River Co		300	210	90	150	..
South Mims	,,	Public well	80	50	50	80		
Spitalfields	,,	Truman, Hanbury and Co.'s Brewery, Brick Lane	300	230	199	331	30	Yield 18,000 gallons a day Tunnels driven into chalk at 285 ft
,,	,,	Ditto, a later well		300	211½	88½		..
Stanmore	,,	Brewery (Clutterbuck's)	328	235	324	239		..
Stanwell	,,	Poyle Paper Mills, near Colnbrook		382	207	175		Most of the water found 203 ft. down
Staines	,,	Middlesex and Surrey Laundries		365	365			..
Throgmorton St.	,,	Warnford Court	.	285	229	56	..	.
Tottenham	,,	Gas Works		114	114			To chalk
,,	,,	Josiah Forster's		125	125	.		Into Woolwich and Reading beds
								Water rose to within a short distance of surface
,,	,,	Longwater, near Park Station		252	148	104		..
,,	,,	Longwater, for Tottenham Local Board		159	150			In Thanet sands, 29½ ft. To chalk
,,	,,	Misses Holt's	6	204	156	54	.	Water rose to a height of 6 ft. above the ground Supply 10 gallons a minute

Tottenham .. .	Middlsx.	..		151½	151½		.	In dead Thanet sand. To chalk
Tottenham Ct. Rd.	,,	Messrs. Shoolbreds, Euston Road	..	370	139	231	200	Supply 800 gallons per hour
,, ,,	,,	Ditto, Mortimer Market	14′ 6″	386·6	142	259	209	,, 6,000 ,, ,,
,, ,,	,,	Ditto, Tottenham Court Rd., Grafton St., W	15	316	124	207	146	,, 6,000 ,, ,,
Turnham Green	,,	Mr. Scott's		318	252	66		To chalk 252 ft.
Twickenham	,,	Brewery, N. of Railway, near Station	35	365	262	138	30	Good supply
,,	,,	Orleans House ..						To chalk about 320 ft.
Twyford . .	,,	..		252	252			Depth to sand 245 ft. 41 ft into Reading beds
Upper Clapton	,,	Connell and Co.		400	120	280	63	Supply 11,500 gallons per hour
Upper Thames St.	,,	Broken Wharf, Messrs Terry's	.	174	69½	104½		.
Uxbridge	,,	Rev H G. Bird		191		.		Yield 300 gallons per hour
Uxbridge Moor	,,	Waterworks		300	83	217	overflows	Two wells, connected by an adit in the chalk (105 ft. to bottom) The second well only 250 ft. deep
Walham Green ..	,,	New Swan Brewery, Messrs Stansfeld & Co	130	290	241	179		Good supply
Wapping . ..	,,	Red Lion Brewery (Hoare and Co)						To chalk 198 ft.
Wenlock Road .	,,	Glovers Brewery	145	141½	155	131½	126	.
Westbourne Estate	,,	Waterworks .		312	297	15		..
,, Grove	,,	Hippodrome	240	67	300	7		
West Drayton .	,,	Rotary Photo Co. .		300	169	131	overflowing	14 ft above surface Pumping 12,000 gallons per hour, but more could be obtained
Waterloo Place	,,	North British Assurance		435	240	195	187	Supply 2,000 gallons an hour
West Drayton	,,	Varnish Works .		260	200	60		To chalk 200 ft
Westminster .	,,	Caxton House .		400	241′ 6″	158′ 6″	154	Supply 2,880 gallons an hour

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Westminster ..	Middlsx	Mutual Tontine Estate Office	7	364	231½	139½	103	Supply 1,500 gallons per hour
Westminster Bridge	,,			187	187		.	8½ ft above Trinity high water mark 160 ft. into blue clay 187 ft to chalk
Whitechapel .	,,	Angel Court, Walton's Sugar-house	112	75	187			In Woolwich and Reading beds
,, .. .	,,	Mr Hill's						Chalk at 150 ft
,, .	,,	Osborne Place, Messrs Kirk and Dyck's	6	190	190	.		Chalk not reached
Whitehall Court	,,	Whitehall Court	7½	443½	229½	221½	179	Supply 6,714 gallons per hour
Whitfield Street	,,	Hooper Struve & Co	13	387	153	247	201	,, 2,500 ,, ,,
Willesden	,,	The Junction Railway Station	20	430	352	98		
,, . ..	,,	Metropolitan Electric Supply Co	20	800 6		through		Through chalk and 80' 6" into hard gault
,,	,,	Neasden .		172	172		68	In London clay or Reading beds; wood and shells were found in the clay
Winchmore Hill	,,			230	230		.	In Reading beds
,, ,, .	,,	New River Co.	180	192' 6"	186' 6"	186	94	.
Anerley ..	Surrey	North Surrey District School	220	252	303	169	102	Supply 7,000 gallons a day of 10 hours
Barnes	,,	West Middlesex Water-works	10	394¾	262¼	142¼	..	..

Battersea . .	Surrey	Edwardes Creameries	19	11		.	17	Ballast Supply 3,500 gallons per hour
,, ..	,,	London and Provincial Steam Laundry Co	13	388	251	150	43	Yield 26 to 30 gallons a minute
Bermondsey .. .	,,	Groves Saw Mills	49	230	150	129	60	Supply abundant
,, . ..	,,	Bowron Bros	7' 6"	343	187½	163	70	,, 2,500 gallons per hr.
,,	,,	Lazenby's		200	134	66		11 ft above O.D.
,,	,,	Peek Frean and Co's Biscuit Works	107	373	107	373	20	Supply abundant
,, ..	,,	E & T. Pink, Ltd	12	235' 3"	152	95' 3"	73	Yield 3,000 gallons an hour
,,	,,	Messrs Oestler and Palmer's		127		.		10 ft. above O.D, to chalk and flints
,, ..	,,	Barrow Bros	8	242	155	95	58½	Yield 3,000 gallons an hour
,, ..	,,	Long Lane	100	49				12 ft. above O.D, yield 6,000 gallons an hour (*to chalk*)
,, . .	,,	Messrs Hepburn	80½	208	184	104½	58	Yield 4,000 gallons an hour
,, .. .	,,	Market Street				60		To chalk 160 ft ?
,, .	,,	Do (*second well*)						To chalk 181 ft.
,, ..	,,	New Weston Street, Messrs Margetson's		179	170	9	74	.
,, ..	,,	Messrs Learmouth and Roberts, Swan St		102	.			To chalk 102 ft, 9 ft. O D.
,, ..	,,	Jute Factory		69½	.			.
,, .	,,	Spillers & Bakers		350	145	205	98	Supply 4,000 gallons an hour
,, .	,,	Willow Walk, Beach's Tan-yard					3 to 4 ft.	To chalk 111 ft., 10 ft. O.D.
,, . ..	,,	Willow Walk, Messrs Oestler and Palmer		333	127	2 6	40	Supply 100 gallons per hour
,, ..	,,	,, ,,	174		108	66	.	Shaft and cylinders throughout
,, . .	,,	Bermondsey Street	.	202		.		3½ ft. below T.H.W mark
Brixton	,,	Belvedere Laundry		400	246	154	133	Supply 4,200 gallons per hour
,,	,,	Hayes Laundry	6	394	240½	159' 6"	106' 6"	,, 7,000 ,, ,,
,, .	,,	London, Gloucester & North Hants Dairy		350	180	170	81	,, 2,520 ,, ,,
Camberwell ..	,,	Camberwell Baths		400	134	266	45	,, 11,550 ,, ,,
,, .	,,	Near Church Street ..	.			.		To chalk 105 ft.

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Camberwell	Surrey	Grove Lane		91				Clay to water at 91 ft.
,,	,,	Cunard St., Albany Rd., Messrs. R. White & Sons	18½	315½	65	269	25½	..
,,	,,	Neate Street, White's Mineral Water Co	12	238	63	187	17½	..
,,	,,	R. White & Sons, Neate Street	12	287′ 6″	80	219′ 6″	18	Yield 5,000 gallons per hour
,,	,,	,, ,,	13′ 6″	352′ 6″	64	302	20′ 6″	Large supply
,,	,,	Cunard Street	11′ 6″	350′ 6″	66	296	27	..
,,	,,	Bagshot Street	10	350	71	289	23	Supply 12,000 gallons per hr.
,,	,,	Warner Road	48	322	163	207	59	,, 11,500 ,, ,,
,,	,,	Neate Street (Rawlings)	13	237	6	182′ 4″	28	
Clapham Common	,,			200				Blue London clay
								Sand with many shells and water basement bed
,, Road	,,	Causton & Sons		425	195	230	54	Supply 12,000 to 18,000 gallons per hour
,, ,,	,,	City & South London Ry. Generating Stn.	5	395	211	189	78	Supply 10,500 gals. per hour
Chertsey	,,	Healy & Co.		700	516	184	overflows	,, 432 ,, ,,
Croydon	,,	Steam Laundry	5	245	175	75	66	,, 1,000 ,, ,,
,,	,,	Page & Overton		230	35	195	15	,, 7,000 ,, ,,
,,	,,	White & Sons	9	347	164	186	32	,, 4,200 ,, ,,
,,	,,	Gas Works, Waddon	40	206¼	108¾	138		Borehole filled up and supply got from the tertiary sands
,,	,,	Workhouse, Queen's Road	63	395	176¼	281½	70	162 ft. above O.D.

Croydon	Surrey	Corporation .. .	4	296	4	296	42′ 8″	Supply 10,000 to 20,000 gallons per hour
Dorking	,,	J. Young & Son	6	179		.	4	Supply 6,000 gals. per hour
Dulwich	,,	St. Saviour's Infirmary	91	214	92	213	..	..
,, ...	,,	At the foot of Herne Hill		53		.	.	In blue London clay
Egham	,,	Mr. Mills					.	Water at 131 ft, through blue clay
,, ...	,,	Staines Waterworks	260	440	354	346	?	Good supply 150 ft. above O D.
Epsom	,,	Waterworks Engine House	50	84			..	These three wells are connected up by a pipe 45 ft below surface
,,		To the S E. .	40	84				Yield 14,000 gallons an hour
,,		In garden	51	135	63¼	123¾	.	,, 12,000 ,, ,, (in summer)
,, ...	,,	Harvey's (late Chandler's Brewery), three wells	35 or 40 one giving section		.		3	It is said that the springs are equal to 25,000 gals an hr.
,,	,,	Horton Manor Asylum	6	444	308	142	56	Supply 1,200 gals. per hour
Ewell .	,,	Chesterfield House		343½		..		125 ft. above O D., in purple (Thanet) sand, 11 ft.
Forest Hill ..	,,	Mr. Swansborough's		276				Through black London clay, gravelly sand and water
,, ...	,,	Mr J. Walker						Ended in chalk at 300 ft.
Fulham .. .	,,	Kops Brewery	5 section	395 of two	242 borings	158	53	Supply 5,000 to 10,000 gals. each
Farnborough	,,	Wey Valley Water works, No 1	50	245	110	185	5′ 3″	Yield 4,000 gallons per hour
,, ..	,,	Ditto, No 2	50	114	110	54	5′ 3″	Supply 4,000 gals per hour
Godalming .	,,	Hon S E. Bouverie, High Barn		303	303		178	,, 1,444 ,, ,, Into clay, 3 ft
,, ..	,,	Goodman Esq., Bowlhead Green		150	150		84	Supply 240 gals. per hour In yellow loamy sand, 2 ft.
Guildford	,,	Friary Holroyd Brewery Co.	.	300	31	269	19′ 3″	Supply 10,008 gals per hour
,, ...	,,	Ditto . .	12	239	24	227	13′ 6″	,, 10,000 ,, ,,

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Guildford ..	Surrey	Waterworks		329	27	302	8	Supply 38,474 gals. per hour
Job at Wincanton	,,	West Surrey Central Dairies, Wincanton	90	157	247		84	In grey sandstone
Guildford .	,,	R. White & Sons		251' 6"			.	Supply 1,560 gals. per hour
Garrett Copper Mills	,,	Near Wandsworth .		143	143	.		,, 3,250 ,, ,,
								About 35 ft. above O D
								Water rose 20 ft. above the ground
								Yielded 120 gals. a minute at the surface
								Woolwich & Reading beds, 52½ or 54½
Garrett ..	,,	The Willows	235		235		overflows	..
,, ...	,,	Garrett Farm		365	365			5 ft. into chalk
,, .	,,	Mr Fenton's		360	355	5		To sand
,, . .	,,	Althorp Lodge .		240	240			,,
Hook ..	,,	Whitehall, 3 miles south of Kingston	48	252	300		17	About 115 ft. above O.D. Water never falls below bottom of shaft
Horley .	,,	Russell Miller, Esq.		67	..			
,,	,,	Tonnel & Elkin .	3	297	300		overflows	At the rate of 9 gals a min.
								Supply pumping 2,000 gals. an hour
Kennington ..	,,	Messrs. Beattie & Co.	..	350	167	183	110	Supply 2,520 gallons per hour
,, .	,,	Hayward Bros. .	..	350	169	181	.	,, 2,000 ,, ,,
,,	,,	South Metropolitan Gas Co.	..	400	183' 6"	216' 6"	98' 6"	,, 1,080 ,, ,,
Kingston-on-Th'mes	,,	Thames Street	.	365	364	.	to surface	River gravel, London clay, 365 ft. to water

Kingston-on-Th'mes	Surrey	Hodgson's Brewery ..	8' 6"	491' 6"	490	10		..
,, ,,	,,	White & Sons . ..	9	606	353	262	2' 9"	Supply 540 gallons an hour
,, ,,	,,	Mr Fuller's, near Cambridge Asylum	..	355	355	.	..	Through (London) clay. Supply 20 gallons a minute. Disused now, and has long ceased to overflow
,, ,,	,,	Union	137	288	..	..	20	To sand spring through London clay
,, ,,	,,	Mr. Palmer ..	..	.	..	.		To chalk 412 feet
Lambeth .	,,	Messrs. Griffiths, Griffin Street		..	.	.	..	,, 213 feet
,, ..	,,	New Union		168	..		..	To chalk. Yield 3,800 gallons an hour. Carried to a depth of 300 ft. Water level 68 ft.
,,	,,	Beulah Laundry ..	.	352	203	149	82	Supply 6,000 gallons per hour
,,	,,	Charing Cross Electric Light		400	222	178	121	,, 6,972 ,, ,,
,,	,,	Daun & Vallentine	8	312	215	105	81	,, 4,000 ,, ,,
,, .	,,	Messrs. J C. & J Field	15	389	225	179	90	,, 7,000 ,, ,,
,,	,,	Workhouse, Renfrew Road	11' 6"	389	170	230	100	,, 10,500 ,, ,,
,,	,,	Near Waterloo Bridge	..	165	165		..	To chalk
,,	,,	Messrs Oakey's Emery Mills, Westminster Bridge Road	105	299	212	192	63	About 12 ft. above O.D.
,, ..	,,	York Mead, Mr Smart's Mill	.	211	211	.	..	To sand and water
Leatherhead ..	,,	Copthorne's Brick Field	74		54	20	..	Shaft throughout. Supply plentiful
,, . .	,,	District Waterworks .	22	178	38	162 ?	..	Water level 2 to 3 ft. above the river. Lowered about 7 ft. by pumping 9 hours at the rate of 15,000 gallons an hour
,, .	,,	Foundation School (St. John's)		100	30	70	..	Average daily consumption about 1,000 gallons

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Limpsfield .. .	Surrey	Cowdrey, Titsea Court	5	381′ 6″	386′ 6″	..	132	Supply 3,516 gallons per hour. In red blowing sand 6″
,, . ..	,,	Limpsfield and Oxted Waterworks	11	339	350		78	Supply 10,000 gallons per hour. In rock 68 ft.
Malden	,,	Mostin Farm . ..	..	314	314	.	4	Into coloured mottled clay (not bottomed)
,, ...	,,	Worcester Park Station, L. & S W. Railway	..	289	289	..	overflows	To sand with water 281 ft. To mottled clay 289 ft. About 70 ft. above O.D.
,, ...	,,	.. ..		401	401	.	to surface	Through blue clay to black sand
Merstham	,,	J. Morgan, Aldbury Farm	26	276	302	.	18	In green sand 13 ft.
Merton	,,	Blue House Farm ..	.	295	295	.	..	To plastic clay
,, ...	,,	Nelson's Fields .. .		225	217	8	.	Water rises 3 ft above the ground, 51 ft above O D.
,, ...	,,	Sewage Works, Croydon Rural Sanitary Authority		164½ to chalk	164½	..	overflow	At the rate of 40,000 gallons a day, recorded as over 52,000. 36 ft above O.D.
Mitcham	,,	Church Road (near Harland's)	255		255	.	overflow	To chalk. Water overflows strongly. 50 ft. above O.D.
,, ...	,,	Collierswood ..		183	183	.	.	To chalk. 52½ ft. above O.D.
,, Lower ..	,,	Messrs. Haywood & Sons	5	250	200	55	4 ft. above surface	Water rose to 4 ft. above surface
,, ...	,,	Hughes and Kimber ..		302		31½	..	..
,, ..	,,	Phipps Bridge . .		255	255			To chalk, (46 ft. above O.D.)
,, .. .	,,	Longley Road	.	194	187	7	overflowed	Level about 55

Mitcham	Surrey	Waterfall Cottages		175	157	18	overflowed	Level about 47
,, ...	,,	Phœnix Villa		235	220	15	.	,, ,, 55
,, .	,,	Acton Terrace		180	168	12	,,	,, ,, 47
,, .	,,	Byegrove House		190	180	10	,,	,, ,, 44
,, .	,,	Clare Villas		180	174	6	,,	,, ,, 40
,,	,,	Greys		220	220			,, ,, 40
,,	,,	New Singlegate Board School		234	220	14	,,	,, ,, 41
,, .	,,	Fountain Cottage		260	260		.	,, ,, 46
,, .	,,	Latham's Varnish Works		260	250	10	,,	,, ,, 50
,,	,,	Lewis Cottages		250?	225	25		,, ,, 63
,,	,,	Gas Works, two wells		250?	225	25?	,,	,, ,, 63
,,	,,	Mitcham House		200	184	16		,, ,, 68
,,	,,	Mr Hatfield's		315	310	5	,,	,, ,, 54
,,	,,	Raven Spring	..	260	220	40	,,	,, ,, 56
,,	,,	Surrey Brewery		225	170	55	,,	,, ,, 68
,, . ..	,,	Baron House .		170	170		overflows	,, 70
,,	,,	Mitcham Hall, Gedge		300	170	130	,,	,, 70
,,	,,	Sampson's Yard .	..	190	180	10	,,	,, 70
,,	,,	Hope Cottages		260	260			Ending in sand, 48 ft. above O D
,, . .	,,	St Saviour's Schools	50	210	260			70 ft above O.D.
,, .. .	,,	C A M W A L . .	3	330		?	19	Supply 1,000 gallons per hour
,,	,,	Gas Works .	136	214	239' 6"	110' 6"	20	,, 3,500 ,, ,,
,, . ..	,,	Thunder and Little	7	333	176	164		,, 3,000 ,, ,,
Morden .	,,	The Green, Lower Morden (public well)	20	365	340	45	water rose to surface	..
Norwood . ..	,,	Western side of Grange Road	120	270	390	.	100	(London clay) to sand with water
,, .	,,	Wilson and Co .		270	270	.	100	..
Nine Elms .. .	,,	Gas Works .		402	219	183	90	Supply 13,000 gallons per hr
,, ,, .. .	,,	Thorne Bros ..	12	339	212	139	54	,, 2,400 ,, ,,
Old Kent Road	,,	Camberwell Baths ..	6	394	35	365	15	,, 15,396 ,, ,,
,, ,,	,,	South Met. Gas Co ..	4	396	47	353	17	,, 6,000 ,, ,,
,, ,, .	,,	Malt St, near Canal Bridge, Britannia Bry.	.	61¾	39	22¼	11	Yield 800 gallons per hour
Peckham . ..	,,	Crutcher's Dairy ..	..	200	61	139	32	,, 1,100 ,, ,,
,, ...	,,	Mr. Griggs	23	101	91	33	40	Supply abundant

PARTICULARS OF WELLS—*continued.*

Name of Place	County	Locality	Depth					Remarks
			Of Shaft	Of Bore	In Tertiary Strata	In Chalk	To Water from Surface	
			feet	feet	feet	feet	feet	
Peckham	Surrey	New Phœnix Brewery	.	300	77½	226′ 6″	41	Supply 4,700 gallons per hr.
,,	,,	North Surrey Brewery	30	151	80	101	25	Yield 2,000 gallons per hour
,, .	,,	White Bros		300	84′ 6″	215′ 6″	38	Supply 2,260 gallons per hr.
,, .	,,	Hill Street Brewery	8	245	86	167	23	Yield 3,600 ,, ,,
,, ..	,,	Messrs. Gordon's Bry., Lyndhurst Rd	115	220½	224	111½	53	Supply 185,000 gallons in 24 hours
Raynes Park . .	,,	Southdown Laundry	..	500	255′ 6″	244′ 6″	15	Supply 8,000 gals per hour
Richmond .. .	,,	Duke of Buccleuch's (*not far from Thames*)	.	257	257		overflow	
,, ...	,,	Waterworks, 160 yards below the bridge	252	1,194	.	through	,,	About 17 ft O.D. Overflow at the rate of 11 gallons a minute, and rose with a force that would cause it to attain a level of 126 ft. above the surface
Rotherhithe	,,		66					To chalk
Southwark	,,	Barclay and Fry, The Grove	4	396	..	198	153	Supply 3,192 gallons per hr.
,, ...	,,	R. H Jenner & Sons, Southwark Bdge. Rd	15	318	203′ 2″	129′ 10″	114′ 6″	,, 4,000 ,, ,,
,, .. .	,,	Bankside No 29, Belfast & London Aerated Water Co	12	288′ 2″	203′ 2″	97	114½	Yield minimum 3,000 gallons per hour
,, . ..	,,	Hibernia Chambers, London Bridge	12	288	198½	101½	95	Yield 1,000 gallons per hour
,, ...	,,	Potts Vinegar Works, Southwark Bdge Rd.	40	120	160	..	91 ?	Chalk at 160 ft
Stockwell .. .	,,	Ingram Houses ..		350	250	100		Supply 1,000 gallons per hr

Streatham	Surrey	Foster & Gregory	67	167	129	105 through chalk	43	
,, Common	,,	Southwark & Vauxhall Water Co	148	1,123	.		45	Bottom beds are various sandstone and rock; large supply from Thanet sands and top of chalk
Sutton Common	,,	Southfields		349	349		17	About 125 ft. above O D.
Southfields	,,	Frame Food Co.		551	320	231	98	Supply 5,000 gallons per hr.
Sutton	,,	The Arches		194	194	.		In Reading beds
,,	,,	L B & S C. Railway		350	2	348	73′ 6″	Supply 40,000 gallons per hr.
,,	,,	Sutton Electric Co		250	14	236	65	,, 5,100 ,, ,,
Sydenham Common	,,	Near Croydon Railway					.	Chiefly in blue (London) clay Lighter sandy soil at 115 ft. Then a conglomerate of broken shells 1½ ft. Blue clay again to a depth of 240 ft Then black graven and sand with a fine spring (Blackheath or Woolwich beds)
Thames Ditton	,,	Lambeth Waterworks Trial boring		385	385		rose to surface	To chalk. Ground surface over 35½ ft. O.D
Tooting	,,	Parker's Nursery		126	126	.	overflowed	Level 45
,,	,,	Fountain Road		115	100	15	,,	,, 40
,,	,,	Ditto, Mr Gardener's		131	121	10	,,	,, 38
,,	,,	Lambeth Cemetery		145	135	10	,	,, 40
,,	,,	Martin's Brickfield		150	145	5	,	,, 40
,,	,,	Lane's Cottages		154	142	12	,,	,, 48
,,	,,	Wallace's Cottages		153	138	15	,,	,, 56
,,	,,	The Limes		140	130	10	,,	,, 54
,,	,,	Eldon House		156	144	12	,,	, 60
,,	,,	Defoe Road, Shellard's		116	100	16	,,	, 49
,,	,,	Brewer's Cottages		126	126	..	,,	, 48
,,	,,	Atlee's Brewery		117	116	1	,,	,, 52
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,,	,,	Betts, opposite the Castle Inn		136	126	10	,,	,, 53
,,	,,	Park House		150	149	1	,,	,, 56
,,	,,	Mr. Gibson's		230	210	20	,,	,, 58

PARTICULARS OF WELLS—*continued*

Name of Place	County	Locality	Depth: Of Shaft	Depth: Of Bore	Depth: In Tertiary Strata	Depth: In Chalk	Depth: To Water from Surface	Remarks
			feet	feet	feet	feet	feet	
Tooting	Surrey	Bell's Farm		80	80	..	overflowed	To grey sand Level 45
,,	,,	The Fountain Inn		90	90	..	,,	20 ft into sand ,, 46
,,	,,	Belts' Cottage	.	95	95	..	,,	To sand ,, 55
,,	,,	The Trafalgar Arms (disused)		130	130		,,	,, ,, 60
,,	,,	The Britannia Inn		136	136		,,	,, ,, 59
,,	,,	Defoe Road, No 1	.	80	80	.	,,	,, ,, 52
,,	,,	Williamson's	.	113	113		,,	,, ,, 54
,,	,,	Near the Church		130	130		,,	,, ,, 58
,,	,,	The Rectory	20	150	170		,,	14 ft in grey sand
Vauxhall	,,	Messrs Barrett & Co, Bond Street	13½	271	207	77½	52	Yield 1,500 gallons an hour
Walworth	,,	Victory Place, White & Co's Mineral Water Works	..	211	147	64		
Wandsworth	,,	Summers Town (Sir J Dunstan's)		195	195		overflowing	To grey sand, 31 ft above O D.
,,	,,	Sadler's Cottages	.	150	150		,,	To grey sand, 32 ft above O D
Wandsworth Road	,,	About 2 miles from Vauxhall		238' 8"	238' 8"	.		In light coloured Thanet sand 32 ft.
,, ,,	,,	Clifton Brewery	211	152	211	152	51	
Weybridge	,,	Chertsey Sanitary Authority (test hole)		55	55	.		Bottom soil 11' 0", blowing sand
Wimbledon	,,	Manor House, 100 yds east of St. Mary's Church	563		563			170 ft. above O.D. Abandoned
,,	,,	Sanitary Laundry	60	353	263	150	14½	Yield 30 gallons a minute, 70 ft above O.D.

Wimbledon	Surrey	Sewage Works, Hayden's Lane	25	375	279	121	nearly to surface	Yield under 10 gallons minute
,,	,,	Hartfield Road		268¼	193¼	75		Level 55 — In all, water either overflowed or reached the surface
,,	,,	Hamilton Terrace	..	200	184	16		,, 47
,,	,,	Woodbine Terrace		192	177	15		,, 46
,,	,,	British Land Co		180	170	10		,, 46
,,	,,	St George's Terrace		180	170	10		,, 42
,, ..	,,	South Road, Corke's Cottages		192	177	15		,, 45
,,	,,	Hayden's Lane Railway Station		180	160	20		,, 50 or 44 ?
,,	,,	The Woodman Inn		355	355			To sand
,, ..	,,	Bunce's Farm		301	301			To grey Thanet sand
,, Common	,,	Eastern side			..			To chalk 465 ft

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